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ADVANCED ULTRA-VIOLET (UV) AIRCRAFT FIRE DETECTION SYSTEM
VOLUME I - SYSTEM DESCRIPTION AND FLIGHT TEST

GENERAL DYNAMICS/FORT WORTH DIVISION
P.O. BOX 748
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FINAL REPORT FOR PERIOD DECEMBER 1977 - OCTOBER 1981

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This technical report has been reviewed and is approved for publication.

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Volume III - Ground Support Equipment (GSE) For System Checkout

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The objective of this program was to utilize ultra-violet (UV) radiation technology to provide advanced means of detecting fire hazards more reliably and more rapidly than current thermally activated continuous cable type systems. The program was divided into four phases. The first phase consisted of analysis and design requirements followed by design and fabrication, environmental testing, and flight testing of the system on an F-111 high performance aircraft.

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20. ABSTRACT (Continued)

The objectives of this program were met. Two ultra-violet (UV) detection systems were developed, fabricated and test flown. The flight test program demonstrated that the systems have a fire detection reliability and a freedom from false warnings that are significantly better than existing service equipment. One system, system A, includes a high degree of redundancy such as dual power supplies, dual sensors and dual microprocessors along with self checking and automatic reconfiguration. These features provide a reduction in pilot work load and reduction in unscheduled maintenance actions. The other system, system B, a simplified system, is based on the same design components as system A but only utilizes a single power supply, single sensor and a single microprocessor. Both systems are considered suitable for near-term service applications.

FOREWORD

The work reported herein was performed in accordance with Air Force Contract F33615-77-C-2029 under the direction of the Fire Protection Branch (AFWAL/POSH) of the Fuels and Lubrication Division, Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio, under Project 2348, Task 01, Work Unit 02, with Mr G.T. Beery and Mr T.A. Hogan, AFWAL/POSH, as Project Engineers.

This report is the result of utilizing ultra-violet (UV) radiation technology in the development and flight testing of an advanced aircraft fire detection system.

The contractor was General Dynamics, Fort Worth Division, Fort Worth, Texas. Mr. R.J. Springer, Program Manager, directed the efforts of P.H. Lang, W.B. Kirk, B.B. Witte, D.C. Nelson, and J. Phillips. The overall effort was under the supervision of Mr. C.E. Porcher, Manager, Propulsion and Thermodynamics Section. Graviner Ltd./HTL Industries, General Dynamics subcontractor, accomplished the design, fabrication, environmental testing and support for the flight test phase of the program. Graviner/HTL's efforts were directed by Mr. S.P. Robinson who was supported by P.H. Sheath and D.J.V. Smith. Sacramento Air Logistics Command (SM-ALC) provided the F-111 aircraft and support for the flight test phase of the program. Mr B.W. Nichols, SM-ALC Engineering, coordinated the flight testing at McClellan Air Force Base.

This report describes the results of work conducted during the period of 15 December 1977 to 26 October 1981.

This is Volume I of three volumes. Volume I describes the overall work of the program which includes the results of the flight test phase. Volume II contains a description and details of the system circuit and software design. Volume III contains a description and details of the Ground Support Equipment (GSE) which is used as a fault diagnostic maintenance tool.

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SUMMARY

Analysis and design requirements were developed for two systems identified as System A and System B. System A included all the basic general design criteria for use in the engine/nacelle areas of high performance aircraft and included design features to reduce false fire indications to a very low probability and increases the ability to detect fires to a value approaching 100 percent. System B design criteria is of simpler design than System A but has the same fast response and high reliability but with lower redundancy.

A trade study was undertaken to determine the merits of a computer control unit versus a hard wired system for this program. Using the analysis and general requirements criteria eighteen different control unit designs were evaluated. This consisted of twelve designs for System A and six designs for System B. Both systems A and B included ultra-violet (UV) fire detector heads, a computer control unit (CCU), and a crew warning unit (CWU). The following optimum systems resulted from the trade off study:

System A

. Dual 115 V.A.C. supply

. Dual microprocessor

. Eight U.V. dual photocell detectors

. Automatic test facilities.

System B

. Single 115 V.A.C. supply

. Hardwired system

. Eight U.V. single photocell detectors

. Manual test facility

. No adjacency.

However, in order to contain the contract within the original financial limits System B was re-configured so that it could be developed as part of System A and thus resulted in a micro-processor based system but with limited redundancy and using single channel detection.

On investigation of possible flight test programs it was determined that the most effective method of testing would be to install System A and System B on alternate engines of a twin engined aircraft and bring their outputs to a simple control panel for the pilot's use. An F-111 was selected as the test vehicle. System A and System B were designed and manufactured to the environmental requirements of the F-111 aircraft with very minor exceptions. A ship set comprising one System A and one System B, each controlling five sets of UV sensing heads, was manufactured and supplied to the Air Force for installation on the test vehicle. It was identified that in order to obtain maximum information from the test program ground support equipment was required. Two such units were manufactured in support of the flight test program and useful additional data was obtained. The flight test program was successful in demonstrating that the original criteria were met i.e. no false alarms and a fully effective fire detection. The only problem encountered was a spurious fault indication on power up of the aircraft which has been remedied during the test flight program.

A final set of flight worthy equipment was assembled with changes that were incorporated in the flight test hardware. This final set of equipment was delivered to the Air Force.

The objectives of this program have been met. A UV fire detection system has been developed, fabricated and test flown on a high performance aircraft. The system has a fire detection reliability and a freedom from false warnings which is significantly better than any existing service equipment. A high degree of redundancy, self checking and automatic reconfiguration is built into the system providing both a reduction in pilot work load and reduction in unscheduled maintenance actions. The system is considered suitable for near-term service applications.

The initial cost of the new system is estimated as being 2.5 times present systems but the total life cycle cost as 0.4 or less.

A logical development of the new system is seen to be the in the incorporation of overheat signalling, where similar reliability improvements can be made at low technical risk.

1.0 INTRODUCTION

1.1 Objectives

The purpose of this program was to develop and test advanced ultraviolet sensitive fire detection systems that have a high degree of reliability, maintainability, and flexibility. The objective was to design a system capable of detecting aircraft engine/nacelle fires within one second, reducing false fire indications to a value approaching 0%, increasing the detection of fires to a value approaching 100%, providing continuous assurance of system operation, and providing indication that the system is incapable of detecting fire. Additionally, system size and weight was to be competitive with existing systems.

1.2 Background

Detection is the first, and probably the single most important factor in the control of aircraft engine fires. If a fire can be detected immediately after it starts, there is a good likelihood that it can be brought under control. On the other hand, if a fire is allowed to become well established before it is detected, the aircraft probably will sustain severe damage and will probably be lost.

1.2.1 Continuous Cable - Type Overheat & Fire Detection

Most current operational USAF aircraft are equipped with thermally activated continuous element (cable type) sensors for the detection of fire and overheat. To detect a fire the direct exposure of thermal energy to a sensor is required and, therefore, the sensors are normally installed adjacent to expected fire risk components in engine installations, which is generally in the nacelle cooling air path. This makes them highly vulnerable to physical damage and a compromise is generally made so that the element is mounted in a somewhat protective manner, i.e., close to skin or alongside structural members. The result is reduced exposure to the air flow, resulting in a lengthened detection time or in some cases, no detection at all.

The service record of cable type sensors with USAF aircraft has not been good. Recent surveys have shown that 33% of actual fire incidents the sensors failed to detect the fires, i.e., if an engine burner-can burns through, the flame will not be detected until secondary damage has occurred. By increasing the sensitivity to the hazard, the number of false warnings increase. The surveys indicate that the frequency of false alarms is as high as 60%. A continual trade-off has been seen between adequate sensitivity to detect hazards, with false fire warnings, and inadequate sensitivity, with reduced false warnings. Also, the location of the sensors makes them liable to physical damage, especially during maintenance operations.

As overheat detectors, the continuous cable type sensors provide excellent protection when installed properly. However, the warning light in the aircraft cockpit does not differentiate between an overheat condition and a fire condition. On some aircraft, these sensors are used to detect failures of engine bleed air ducts in critical areas but they have experienced limited success due to the restriction of providing full coverage around a duct.

1.2.2 Ultra-Violet (UV) Fire Detection

Ultra-violet measurements of solar energy and fires over the wavelengths 200 to 320 nanometers (nm) have shown that wavelengths exist below 280 nm, where the energy from a fire is greater than that from the sun. This is because the energy from the sun is filtered by the earth's atmosphere.

This technology has lead to the development of a fire detector for aircraft use that exploits this phenomenon, thus producing a UV detector that can detect fires in the presence of sunlight and yet not respond in any way to the sunlight.

Figure 1-1 shows the relative response of the HTL/Graviner UV detector cell in conjunction with the emission of fire and sunlight. The peak sensitivity at 220 nm is typically more than 30 million times greater than the sensitivity at 290 nm. This very large difference in sensitivity is important because the amount of short-wavelength power radiated by a flame is only a small proportion of the total power radiated by the flame and is also small compared with the power of other longer-wavelength signals found in the aircraft environment and to which the sensor must not respond. The ability of the UV sensor to discriminate between a real fire and background radiation depends principally on the use of a sensor which is very responsive to radiation of 200-240 nm wavelengths and relatively insensitive to radiation of longer wavelengths.

The HTL/Graviner UV sensor is essentially a borosilicate glass envelope containing metal electrodes and a low-pressure gas filling.

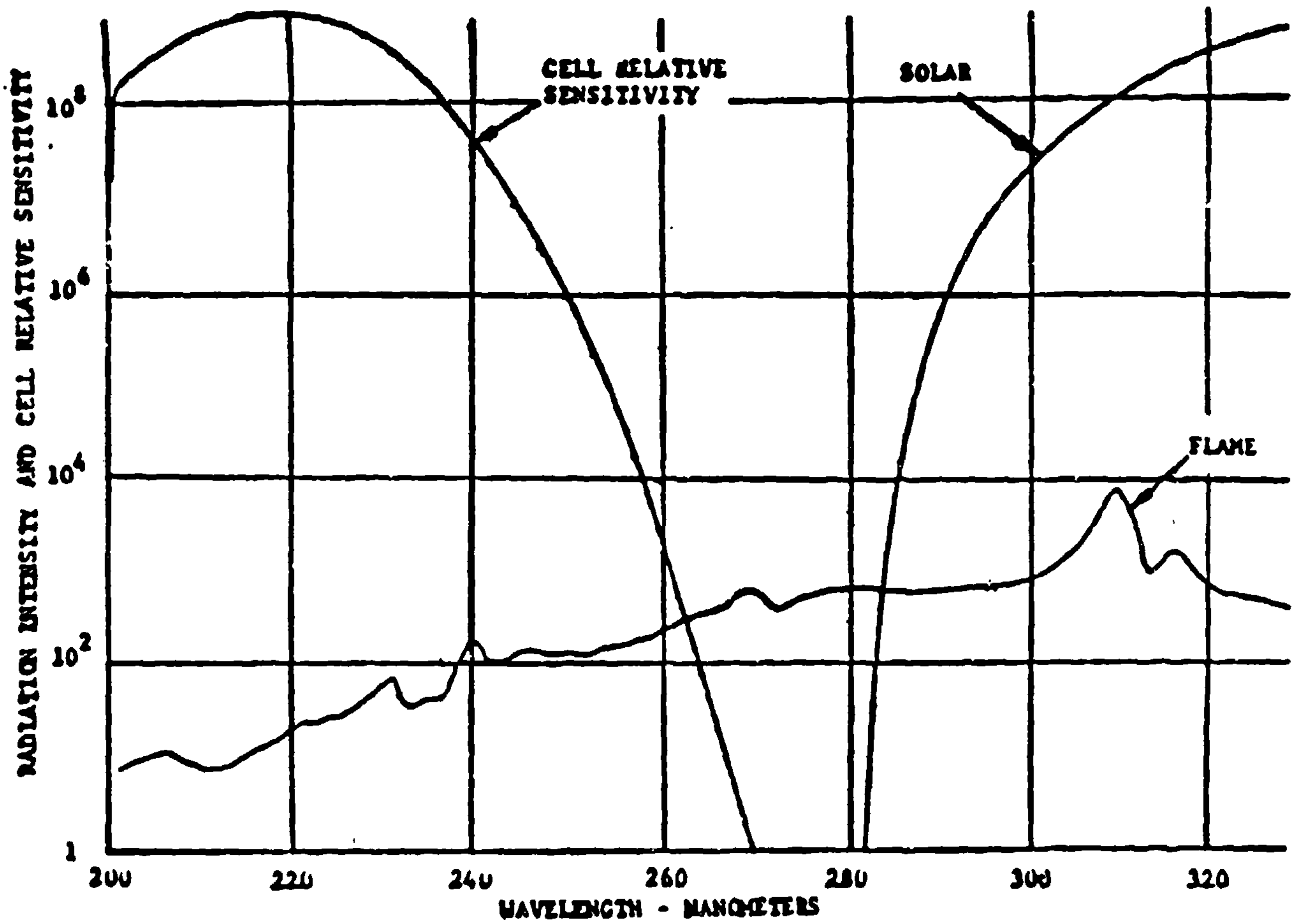

FIGURE 1-1 U.V. DETECTOR SPECTRAL SENSITIVITY COMPARED WITH FLAME AND SOLAR RADIATION SPECTRA

In operation, 320V D.C. is connected across the two sensor electrodes and incident photons of sufficient energy cause the emission of an electron from the negatively charged electrode. If the electron is not re-trapped in the cathode, it will accelerate in the electric field and gain sufficient energy to cause ionization of a gas molecule. The electron released can cause further ionization while the positive ion returns to the cathode with a chance of causing secondary electron emission on collision. When the secondary electron emission exceeds the primary electron emission, the condition is right for breakdown of the gas and the tube conducts. Signal amplification is approximately 10^{12}.

The circuitry of an associated signal processor is arranged to switch off the tube when breakdown occurs and then re-establish the electrode voltage to await the next arrival of photons with sufficient energy. Each time breakdown occurs, the signal processor registers one count and if the count rate exceeds predetermined conditions, an alarm signal is indicated.

However, certain 'noise' signals such as lightening, cosmic and solar radiation at altitude may also cause the sensor to conduct.

In order to differentiate genuine fires from the 'noise' signals, control circuits are arranged so that not just one but several counts are required in a pre-determined time period to initiate an alarm sequence. The time period is selected so that there is a high probability of warning from flame radiation but a very low probability of warning from any background radiation.

The detector sensitivity, as noted above, is described in terms of counts per time period, since the system counts each time photons of sufficient energy arrive at the sensor. Since the counts produced arrive in a poisson distributed manner, the sensor can not be described as being responsive or not responsive to a particular incident power, but rather as having a definable probability of responding to a particular incident power.

Thus, if a particular time period (or gate) is selected and logic circuits arranged so that a signal is produced only when N or more counts occur within that period, then the probability of responding to a flame or solar radiation can be determined. In this case, for example, a 167 msec gate time and logic circuits that demand 4 counts or more within the gate will show a probability of .9992 of responding to the MIL-D-27729A pan fire at 4 feet and a probability of 0.000057 of responding to worst-case solar radiation.

It should be noted here that MIL-D-27729A specifies the fire to which a UV detection system must respond. The fire is set to burn in a 5 inch diameter container (pan) and must be detected at a minimum of 4 feet away.

Signal/noise enhancement techniques have also been employed in the system because with a gate time of 0.167 seconds, high energy short duration lightning flashes will fill a gate.

In the case of System B, three such gates consecutively filled in one second are needed to generate a fire warning.

In the case of System A, six consecutive gates are required; 30 on channel A and 3 on channel B.

Now for System A, the possibility of detection is decreased slightly to 0.995 whereas the possibility of alarms due to worst-case solar radiation is 3.5×10^{-26}.

The general aim in selection of gate times, counts/gate, and number of gates is to achieve a high probability of warning to flame radiation but a very low probability of warning to unwanted signals, taking into account the required response time of the system. As has been implied previously, 'response time' does not have the same meaning in the probability situation as in conventional level-sensing fire detection systems. For example, taking the case of System A with a signal strength less than the pan fire, of 40 counts/second average, an apparently low probability of 0.531 is shown for response to the pan fire in 1 second. In fact, this probability of responding increases sharply for each incremental addition of a gate time so that by 2 seconds the probability is 0.85, by 3 seconds the probability is 0.957, and so on. See Figure 1-2.

Figure 1-3 shows System A and System B probability of generating a warning in one second with varying signal strengths. The signal strength obtained from the specified pan fire is 80 counts per second average.

Further refinements are included which increase the sensitivity of the system once a fire warning has been signalled. The effect of this is to hold on the fire signal under the test condition where half of the MIL-SPEC pan fire is obscured. In this held on condition, there is an increased probability that the signal could also be held on by unwanted inputs such as solar radiation, but it can be readily shown that this probability is insignificant in relation to the permitted re-set time of the system.

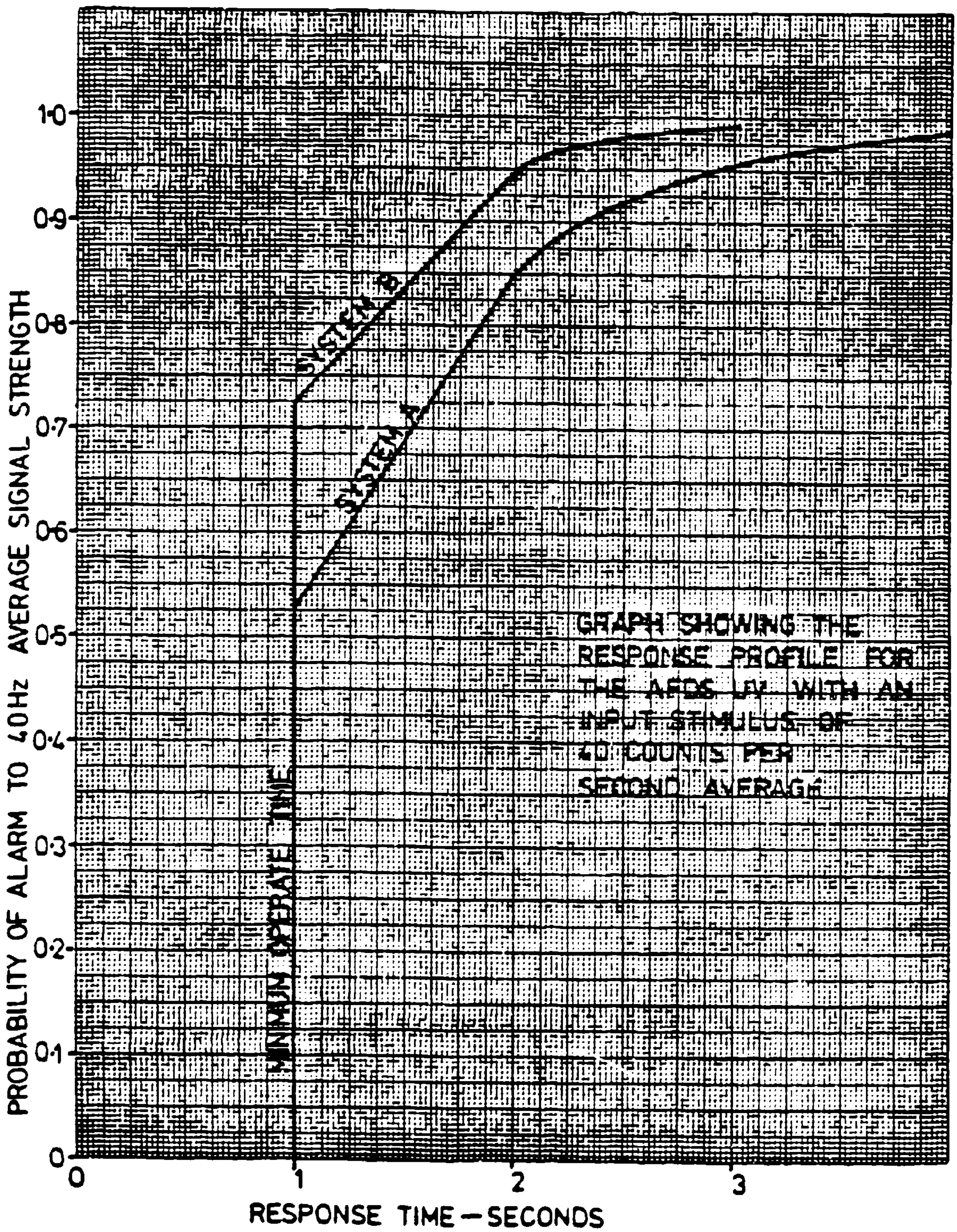

FIGURE 1-2 RESPONSE OF HALF PAN FIRE; 40 COUNTS PER SECOND

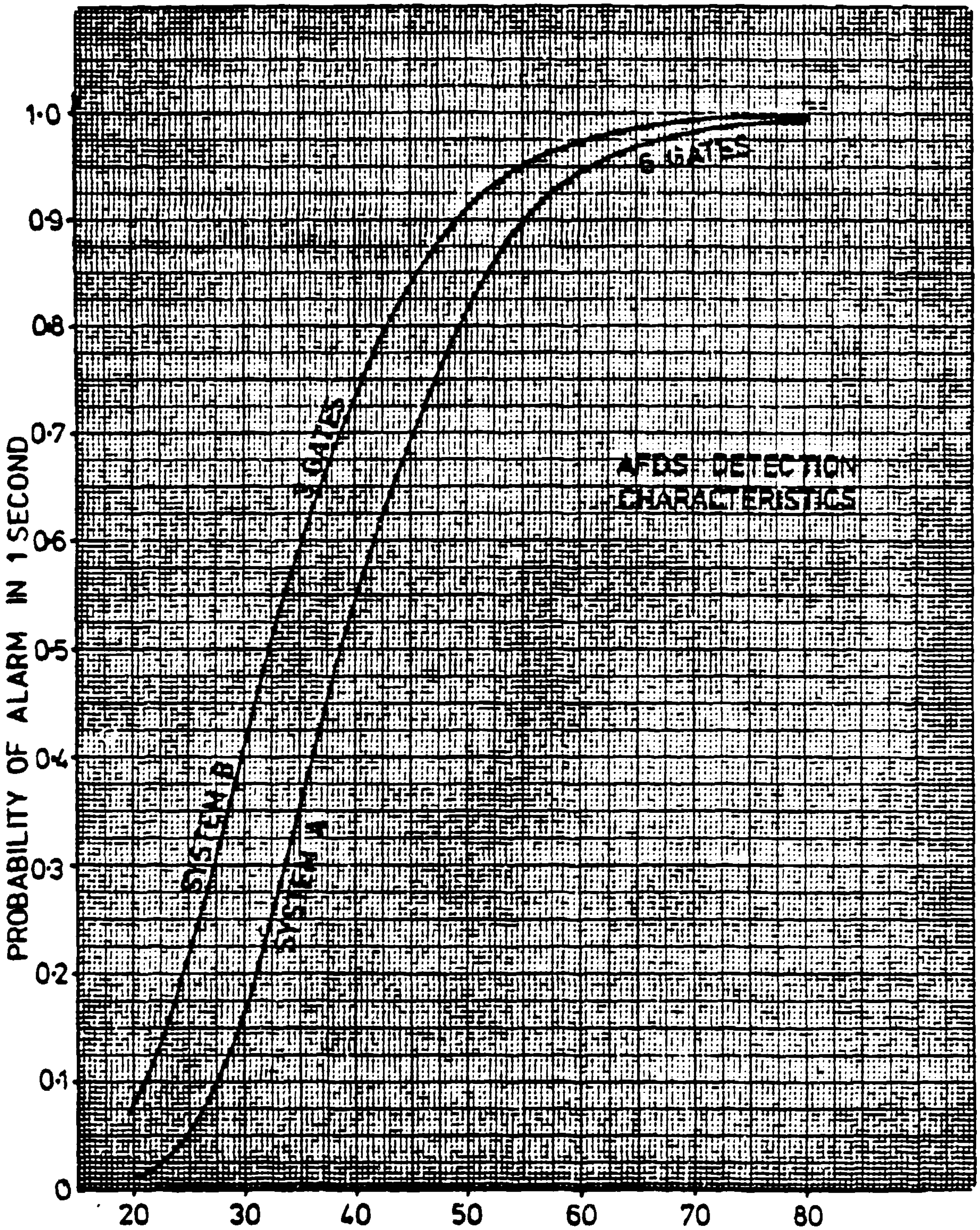

FIGURE 1-3 PROBABILITY OF RESPONSE IN 1.0 SECOND

1.3 Test Program

The overall program approach was to develop two fire detection systems, identified as System A and System B. System A was identified for use in the engine/nacelle areas of high performance aircraft, i.e., F-111 aircraft. Design features were to reduce false fire indications to a very low probability and to increase the ability to detect fires to a value approaching 100 percent. The design criteria was based on the concept that a level of subsys[illegible]ures could be tolerated, provided fire protection capa[illegible]as maintained. Above a certain level of system failure, the p[illegible]ld be alerted that he no longer had an adequate fire detection system.

System B was identified for use in less demanding environments such as dry bay areas (equipment bays) and engine nacelle areas of subsonic aircraft, i.e., pod-mounted engine bays. Design criteria was to be of simpler design than System A, having the same fast response and high reliability but with lower redundancy.

Both systems were to be designed such that routine maintenance actions would allow subsystems that had failed to be identified and repaired or replaced. This required the development of ground support equipment (GSE) to be used as a fault diagnostic maintenance tool. The GSE would also permit identification of any trend towards unserviceability of the subsystems and of the flight performance of the system.

The program was divided into the following phases:

Phase I - System Requirements Analysis and System Specification

Phase II - Detail Design and Fabrication

Phase III - Performance and Environmental Tests

Phase IV - Flight Tests and Evaluation

The system requirements and analysis (Phase I) was to establish the design configuration of the systems and their components. This analysis was to consider the geometry and environment of high performance aircraft engine nacelles under all aircraft operating conditions, including in-flight and ground, and to determine the optimum fire detecting system configuration.

Factors to be considered included probable fire locations based upon combustible fluid sources and ignition sources, probable fire paths under both combat damage and non-combat conditions, temperature regimes, air flow patterns, and physical obstructions to line of sight viewing. The analysis was also to determine the number and location of UV detector units to provide full coverage of the nacelle fire area assuming the loss or failure of any one detector unit.

The program technical approach involved the use of Graviner's high reliable and flight qualified UV detector tubes, the design and fabrication of the computer control unit (CCU) and the crew warning and monitoring unit (CWU) from established technology. These three components (UV detectors, CCU and CWU) were integrated to form complete fire detection systems (Systems A and B) suitable for installation in advanced aircraft.

Since the UV detector technology was available and the design of the CWU was relatively simple, the primary design and development effort was directed towards the CCU. Two candidate CCU designs were evaluated by both General Dynamics and HTL/Graviner: microprocessors and discrete (hard-wire) switching circuitry. Trade studies were performed as a part of the Phase I effort to provide a comprison of these two candidates in terms of performance, weight, volume, reliability, maintainability, and cost so that a CCU design approach could be selected for detailed design and development.

Detail design and fabrication (Phase II) of Systems A and B were to be made for qualification testing. This consisted of component design, reliability and maintainability studies, and preliminary system safety analysis. Also, a detailed installation design and flight test plan was made for an F-111 aircraft.

Performance and environmental qualification tests (Phase III) included flame sensitivity, exposure to flame, functional characteristics, response and reset times, and exposure to high and low temperatures, thermal shock, humidity, altitude, acceleration, vibration and mechanical shock.

Flight tests and evaluation (Phase IV) consisted of installing systems A and B on an F-111 aircraft. Analysis and evaluation of performance, reliability and maintainability was made in the F-111 operational environment.

2.0 SYSTEM REQUIREMENTS

2.1 Fire Signal Parameters

2.1.1 Requirements

The following parameters have been used in calculating the best signal to noise ratio for system design.

a) Signal strength is 80 pulses per second (pps) from the sensor when offered up to the specified pan fire.

b) Half signal strength is 40 pps.

c) 'AND' logic is incorporated. This means that in the following, the number of gates* quoted is, in fact, the two halves of the 'AND' system added. Time sharing is incorporated.

d) Operate times up to 1 second only have been calculated. Even greater signal to noise ratios can be achieved by increasing the response time above 1 second.

e) The noise level is 1.5 pps and is equivalent to the worse case sensor at the worst position on the earths surface.

*Note: "Gate" is the length of time the sensor is 'on line', and is the time period for collecting pulses, after which the counter is set to zero.

2.1.2 Calculations

Tables 2-1 through 2-5 show the effects of increasing the gate time of the sensor.

The calculations are based on a Poisson distribution of pulses obtained from the sensor.

2.1.3 Conclusions

Other effects which do not show in the above tables are:

a) Lightning

It is thought that a lightning flash can exceed 100 mS duration. Thus, single low time gates can be excluded.

TABLE 2-1
GATE TIME 50 mS

Response time Secs		0.1.	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
No of gates		2	4	6	8	10	12	14	16	18	20
1 pulse per gate	P80	96.4	92.9	89.5	86.3	83.1	80.1	77.2	74.4	71.7	69.1
	P40	74.8	55.9	41.8	31.2	23.4	17.5	13.1	9.8	7.3	5.5
	MTBF	9.6S	30M	4D	2.1Y	408Y	$7.8.10^{4}$	$1.4.10^{7}$	$2.9.10^{9}$	$5.5 10^{11}$	10^{14}
2 pulses per gate	P80	82.5	68.1	56.2	38.3						
	P40	35.3	12.4	4.4	1.5						
	MTBF	1.9H	31Y	4.10^{6}	6.10^{11}						
3 pulses per gate	[illegible]	58	33.7	19.6							
	40	10.5	1	0.1							
	MTBF	131D	8.10^{7}	$1.8.10^{16}$							

NOTE: MTBF Is the mean time between false warning due to 1.5 pps.

P.80 is the probability of a Fire Warning at 80 pps.
P.40 " " " " " " 40 "

S = Seconds D = Day H = Hours.
M = Minutes Y = Years.

TABLE 2-2
GATE TIME 100 mS

Response time		0.2	0.4	0.6	0.8	1.0 secs
No of gates		2	4	6	8	10
1 pulse per gate	P80	99.9	99.87	99.8	99.7	99.67
	P.40	96.4	92.8	89.5	86.3	83.1
	MTBF	5.15S	4.4M	3.8H	8.2D	1.2Y
2 Pulses per gate	P.80	99.4	98.8	98.2	97.6	97
	P40	82.5	68.1	56.2	46.4	38.3
	MTBF	16M	107D	$2.8.10^3$	$2.7.10^7$	$2.6.10^{11}$
3 pulses per gate	P80	97.3	94.6	92	89.5	87.1
	P40	58	33.7	19.6	11.4	6.6
	MTBF	4.6D	5.10^4	2.10^{11}	$7.7.10^{17}$	3.10^{24}

TABLE 2-3
GATE TIME 150 mS

Response time		0.3	0.6	0.9	1.2 Secs
No of gates		2	4	6	8
2 pulses per gate	P80	99.98	99.97	99.95	99.94
	P40	96.6	93.2	90	86.9
	MTBF	5.3M	7.6D	44.1Y	$9.3.10^4$
3 pulses per gate	P80	99.9	99.8	99.7	99.6
	P40	88	77.4	68.1	59.9
	MTBF	16.1H	716Y	$2.8.10^8$	10^{14}
4 pulses per gate	P80	99.5	99.1	98.6	98.2
	P40	72	51.9	37.4	26.9
	MTBF	218D	$7.4.10^7$	$9.4.10^{15}$	$1.2.10^{24}$

TABLE 2-4
GATE TIME 166.6 mS

Response time		0.33	0.66	1.0 Secs
No of gates		2	4	6
2 pulses per gate	P80	99.99	99.99	99.99
	P40	98.1	96.2	94.3
	MTBF	4M	3.9D	15.3Y
3 pulses per gate	P80	99.97	99.93	99.9
	P.40	92.5	85.6	79.2
	MTBF	9.9H	242Y	$5.1.10^{7}$
4 pulses per gate	P80	99.8	99.67	99.5
	P40	80.8	65.4	52.8
	MTBF	108D	$1.7.10^{7}$	$9.4.10^{14}$
5 pulses per gate	P80	99.4	98.8	98.2
	P40	63.1	39.8	25.1
	MTBF	120Y	$2.8.10^{12}$	$6.3.10^{22}$

TABLE 2-5
GATE TIME 0.25 SEC

Response time		0.5	1.0	1.5 Secs
No of gates		2	4	6
7 pulses per gate	P80	99.95	99.9	99.85
	P40	75.67	57.25	43.32
	M	$3.6.10^{5}$	$1.6.10^{19}$	7.10^{32}
8 pulses per gate	P80	99.84	99.7	99.5
	P40	60.8	37	22.5
	M	$1.6.10^{8}$	$2.3.10^{33}$	7.10^{40}
9 pulses per gate	P80	99.6	99.17	98.75
	P40	44.5	19.8	8.8
	M	$9.4.10^{10}$	10^{30}	$1.3.10^{49}$
10 pulses per gate	P80	99	98	97
	P40	29.4	8.6	2.5
	M	$4.7.10^{13}$	$2.7.10^{35}$	$1.6.10^{57}$

b) <u>Background Level</u>

It is known that a background level of radiation can be obtained from such things as cosmic. Although this occurs at a very low level, it means that single-pulse per gate systems should not be used if possible.

c) <u>Half Signal Strength</u>

In order to lock onto a pan fire at half intensity once it has warned, it is necessary to count half of the counts per gate.

d) <u>Half System Failure</u>

Should half the 'AND' system fail then the half system left should still be capable of generating a fire warning. This is considered in the final conclusion, to give a good noise immunity.

2.1.4 Final System Design

Response Time	1 second
Gate Time	0.167 seconds
Pulses per gate	4
No. of gates/system	6
∴ No. of gates/sensor	3

Probability of detecting the specified pan fire in 1 second is 99.5%.

Probability of a false warning due to solar is 5.6×10^{-24}

or 1 per $9.4 \times 10^{+14}$ years.

Thus, the system should be designed such that after a fire warning has been given the warning will be maintained at 2 pulses per gate.

Hence, the probability of maintaining a fire warning:

a) With full pan fire is 99.99%

b) With half pan fire is 94.3%

It should be noted that the probability of sensing a half pan fire is 52.8% in the specified time of 1 second.

It should be noted that in times above 1 second, the probability of detecting the pan fire increased towards 100%.

If the system is now run on half of the 'AND'. logic to give a fire alarm, the false warning rate from solar is decreased from 1 per 9.4×10^{14} years to 1 per 1.3×10^{4} years.

2.1.5 Tolerance Effects

The design is based upon nominal signal strengths fron the U.V. detector when viewing a 5 inch pan fire.

Figure 2-1 shows the effect of worse case U.V. detector parameters upon the response of the system.

The probability theory can be applied to the electronics assuming the signal strength from the U.V. detector varies. This produces the curve of signal strength, versus probability of detection within 1 second (Note: If the time is increased, the probability increases, therefore, the fire will always be detected if the time is long enough). From the curve at 20 pulses per second, there is still a probability of 0.6%. Therefore, fires can be detected smaller than the 5" pan fire in 1 second, but with a low probability.

The worst case limits for the U.V. detector include all specification variations.

2.1.6 Effects of Lightning on U.V. Equipment

The effects of lightning are based on reported observations and those of K. Berger who observed lightning on Mt. San Salvadore in Switzerland (Reference 2-1). He found that lightning existed from 0.5 to 1.5 seconds with a small number of occurrences longer than 1.0 second. Based on the analysis of this data it was concluded that the response time should remain at 1 second with 0.167 gate times.

2.2 Other Considerations

This analysis is required to consider the geometry and environment of high performance aircraft engine nacelles under all aircraft operating conditions, including in flight and ground, to determine the optimum fire detecting system configuration. In doing this, it is required to consider in particular the F-111 aircraft and other high performance aircraft and conceptual designs through the 1992 time period, to provide a basic broad application of the detector system.

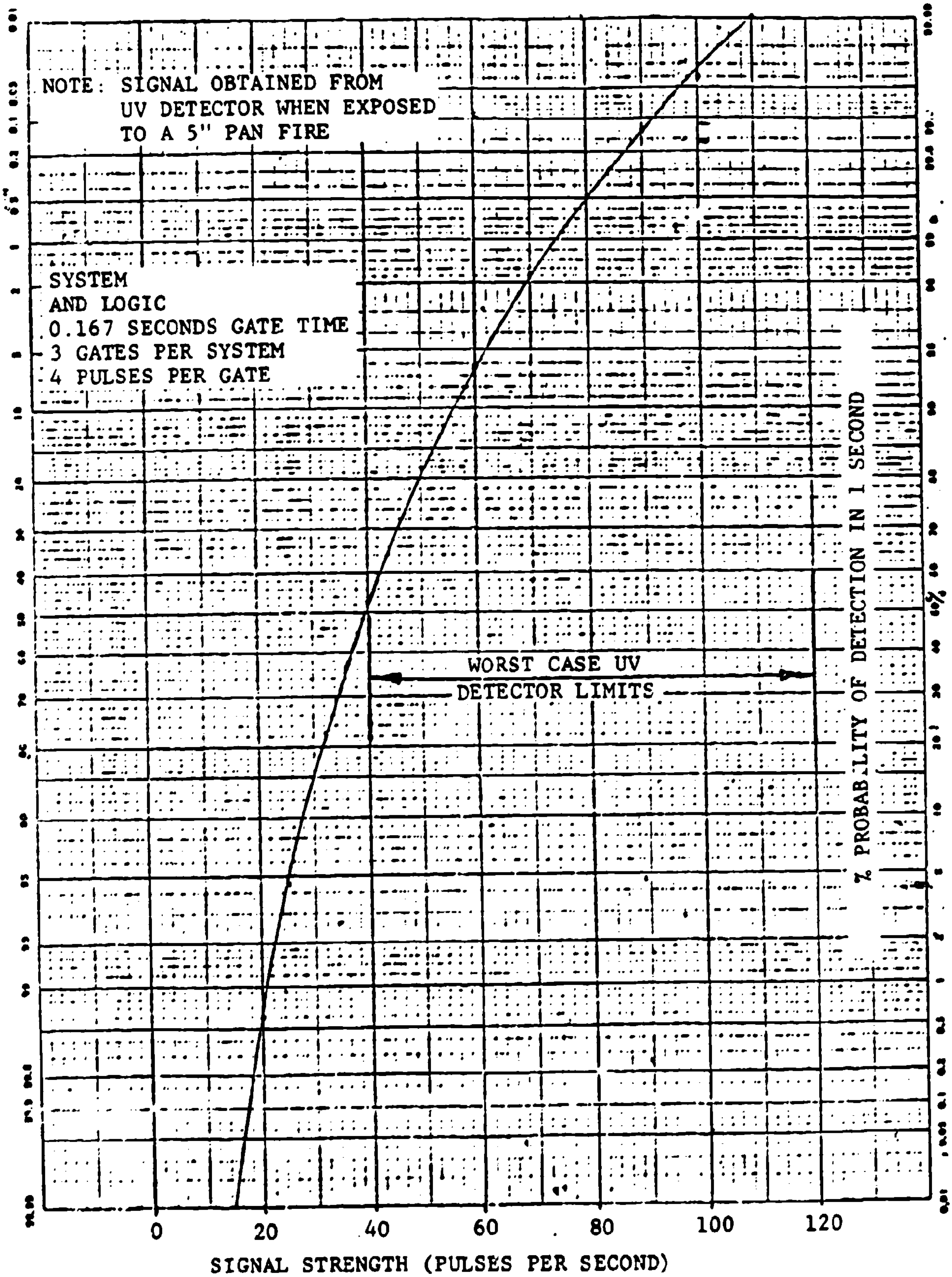

FIGURE 2-1 SIGNAL STRENGTH

2.2.1 General Considerations

In deciding the number and position of the detectors required for the most effective fire protection within the engine nacelle of a high performance aircraft, the following points must be considered.

a) The detector will have a direct view of the locations of all likely fire hazards.

b) The detector should be accessible to permit cleaning.

c) The detectors will be positioned so that there is no direct viewing of light sources external to the engine nacelle, (such as afterburner plumes).

d) The detectors should be located where damage is unlikely during engine removal or maintenance.

e) The detector will not be located close to hot exhausts in excess of 250^{o}C.

f) The detector should be situated facing "down wind" to minimize the contamination accumulation on the optical surfaces.

g) Any one location of a possible fire hazard will be covered by viewing area of at least two detector units, so that the system may operate satisfactorily with the loss or failure of any one detector unit.

When locating a detector for a particular application, it is not always possible to comply with all the above considerations, and the best compromise must be reached.

2.3 System Design Criteria

The basic criteria for the system design is developed from the requirements in the Statement of Work. The criteria laid down in the Statement of Work can be restated as "The ideal fire and detection system would reliably detect every incident that arises, would not itself cause any operational problems and would also have zero weight and zero life cycle cost!"

The aim in fitting a fire detection system is of course to reduce the total hazard to which an aircraft is exposed. The degree of success in achieving this aim is not just a function of the fire detection system itself, but also of the installation on the aircraft and the effectiveness of the fire drills.

Figure 2-2 is a representation of the total fire related hazard situation when a fire detection system is fitted. The precise levels of severity of hazard are arguable, but it is reasonable to suppose that a detected fire is considerably less hazardous than an undetected fire, and that a false warning is less hazardous than a detected fire because presumably no other engine fault exists.

Area 'a' represents failure to detect a fire, while area 'c' represents an additional hazard introduced as a consequence of fitting the detection system. In order to achieve maximum hazard reduction it is aimed to reduce areas 'a' and 'c' to as close to zero as possible, this gives rise to the normal definition of system reliability which states that a system should have a <u>high probability of signalling when a fire hazard exists and a low probability of falsely signalling a fire when the hazard is absent.</u>

This is a reasonable first definition although it does not take account of the relative importance of the two factors, in particular of the enormous cost of failing to detect a fire.

2.3.1 Fire Detection System Requirements

As noted previously, a high reliability fire detection system should have a high probability of detecting a hazard and a low probability of false warning. In addition, it is desirable that the greater emphasis is placed on detection capability.

In order to meet this aim, the important performance characteristics that should be sought in a continuous cable type fire detection system are as follows:

a) The system should be as sensitive as possible to fire conditions.

b) The system should have an extremely low probability of failing in such a manner that it is unable to detect a fire.

c) The system should be free from false warnings.

2.3.1.1 System A Design Criteria

From the above it will become clear that the primary goal of system A design requirements should be:

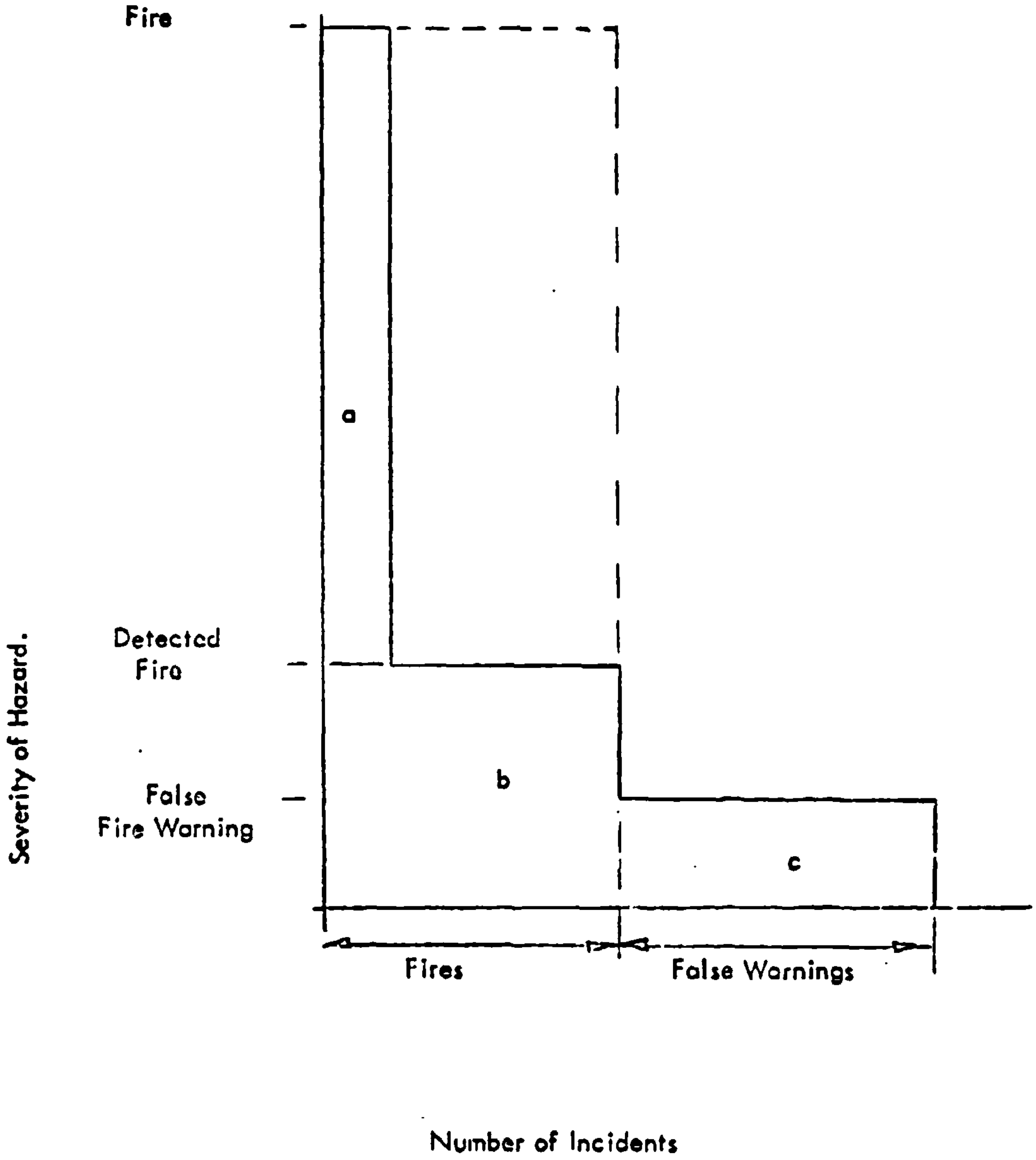

FIGURE 2-2 FIRE RELATED HAZARD POTENTIAL

a) That in the event of partial systems failure or total failure of one or more detector units, the system shall not false warn, shall not alert the pilot, shall continue to operate as a fire detection system. It will be seen that in this situation some means of system interrogation must be made available as otherwise failures of sub-systems would build up to a point where total systems failure would occur.

b) The system A configuration was, therefore, based on a concept that a level of systems failures could be tolerated providing fire protection capability was maintained. Above a certain level of system failure, the pilot would be alerted that he no longer had an adequate fire detection system, but prior to that level being achieved, routine maintenance actions would allow subsystems that had failed to be identified and repaired or replaced. Thus, effectively the availability of the system for fire detection would become independent of the mean time between failure of the system components, i.e. a redundant system.

2.3.1.2 System B Design Criteria

The Statement of Work defined system B as being a lower environmental requirement system and a fundamentally simpler system. Review of the specifications of the hardware to be incorporated on system B, indicated that reduction in environmental requirements would have no bearing on simplification of the design. System B has, therefore, been considered to work at the same environmental levels as system A and it is, therefore, suitable for fitting to military aircraft in engine nacelles. The reduction in complexity of system B was brought about by the removal of the requirement for self-checking features on an automatic basis, and the removal of the requirements for redundancy. The requirements for manually initiated self-test was left in the system design, however, and review of this facility as part of the trade study indicates that the implications of removing this feature need further discussion.

2.3.2 Passive Versus Active Failure Modes

The majority of continuous fire detection systems currently being flown on U.S. military aircraft are of such a design that in the event of a failure the system fails 'active', thus, causing a false warning condition. The result of this failure mode is of course that the false warning is investigated at the end of the mission, and rectification is put in hand. Since rectification is therefore carried out in the event of a failure (when systems fail active) systems that fail in this manner do remain effective as fire detection systems throughout the life of the aircraft. Note: The same cannot be said for systems which fail in a passive mode and which are not capable of being checked in a fully "end to end" manner.

The U.V. flame detector system is primarily a passive failure mode system, in that the most likely failure modes are contamination of the tube surface, wires breaking or being shorted together. All these failure modes will, in fact, result in passive failure, in that they will not cause the control unit to signal a fire. Thus, without any comprehensive systems testing the resultant situation would be that large number of fire detection systems, while originally perfectly satisfactory, would over a period of time, and a number of missions, become non-effective, and thus, the aircraft would be flying without viable fire detection systems on board. Note: Again a parallel can be drawn with certain continuous detector systems currently flying on American military aircraft. It is thus, considered to be essential that for a system such as this, some fully comprehensive test system be incorporated which can be initiated by ground crew or pilot prior to mission. The system proposed is that a U.V. emitter be mounted external to the envelope of the detector tube, and be energized (on system B) by manual action prior to mission. The system will then signal a fire warning which will confirm that the system is operational, right from the detector through to the crew warning unit. It was not considered adequate to simply electronically check the control unit and the wire going to the detector units. Note: Comparison can be drawn with current continuous detector system flying on American military aircraft.

Unfortunately, the Trade Study does not allow detailed analysis of the passive failures over multi mission activities, simply because not enough information is available on the mission profile of the aircraft involved. Thus, comprehensive self-test systems invariably resulted in an apparently less optimal system design. However, because of the arguments given above, this element of the Trade Study was ignored.

3.0 TRADE STUDIES AND PREFERRED SYSTEM DESIGN SELECTION

3.1 Trade Studies

Since the U.V. detector technology was available through Graviner's extensive experience the main effort was to develop the Computer Control Unit (CCU) logic circuits and hardware. This trade study was to ensure that the proven high reliability was maintained with the requirements of response time, fire warning/fault warning logic and automatic self test. The trade study was undertaken to determine the merits of a computer control unit versus a hard wired system.

In order to achieve a design with the maximum impact on life cycle costs and effectiveness, eighteen serparate designs were analyzed; twelve for System A and six for System B.

3.1.1 System A

System 1 was chosen as the initial A system and the remaining A systems were compared with it.

System 1. Dual 28V Supply With 2 Microprocessors

The system has two internal 28V D.C. power supplies supplying two microprocessor based control electronics. Using this system, should either a power supply or a microprocessor fail, the system still functions as a fire detector, as the remaining power supply and microprocessor still function correctly.

System 2. Dual 28V Supply With Hardwire

System 2 is identical in performance to system 1, but has a hardwire electronic control instead of two microprocessors.

System 3. Single 28V Supply With 1 Microprocessor

This system has all the capabilities of an A system, but should either the internal 28V D.C. supply or the microprocessor fail, the system fails.

System 4. Single 28V D.C. Supply With Hardwire Circuit

Single 4 is as system 3 except the single microprocessor has been substituted by hardwire circuitry.

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System 5. Dual 115V A.C. Supply With 2 Microprocessors

This system is as system 1 except it utilizes two 115V D.C. supplies instead of two 28V D.C. supplies.

System 6. Dual 115V A.C. Supply With Hardwire Circuit

System 6 is as system 5 except that the two microprocessors have been replaced by an equivalent hardwire circuit.

System 7. Single 115V A.C. Supply With 1 Microprocessor

System 7 is the equivalent of system 3 except the 115V supply replaces the 28V D.C. supply.

System 8. Single 115V A.C. Supply With Hardwire Circuit

This system is identical in operation to system 7 but uses hardwire circuits instead of a microprocessor.

System 9. Single 115V A.C. Supply With 2 Microprocessors

Utilizing this system enables one microprocessor to fail and the system still functions as a fire detector. However, should the internal power supply fail, the system fails.

System 10. Single 28V D.C. Supply With 2 Microprocessors

System 10 is as system 9 except that the 115V A.C. supply has been replaced with a 28V D.C. supply.

System 11. Dual 28V D.C. Supply With 1 Microprocessor

In this system should one power supply fail the system still functions correctly using the second supply. However, should the microprocessor fail, the system fails.

System 12. Dual 115V A.C. Supply With 1 Microprocessor

This system is the equivalent of system 11 except the 28V D.C. supplies have been replaced with 115V A.C. supplies.

3.1.2 System B

All B systems have manual test facility. System 13 was chosen as the initial B system and the remaining B systems were compared with it.

System 13. Single 28V D.C. Supply, Hardwire Circuitry
No Adjacency

As stated this system is a single 28V D.C. supplied unit, with hardwired circuitry. In the A systems above there is adjacency of U.V. detectors. That is, each fire risk area is viewed by two U.V. detectors and both must respond to enable a fire warning to be indicated. This system has no adjacency. That is, although the fire risk area is viewed by two U.V. detectors, only one responding gives a fire warning indication.

System 14. Single 115V A.C. Supply, Hardwire, No Adjacency

System 14 is the equivalent of system 13, only using a 115V A.C. supply instead of a 28V D.C. supply.

System 15. Single 28V D.C. Supply, 1 Microprocessor, No Adjacency

This system is the equivalent of system 13 except the hardwire circuit has been replaced with a single microprocessor circuit.

System 16. Single 28V D.C. Supply, 1 Microprocessor, With Adjacency

Identical to system 15, this system has adjacency as an included extra.

System 17. Single 115V A.C. Supply, 1 Microprocessor, No Adjacency

System 17 functions as per system 15, except the 28V D.C. supply has been replaced by a 115V A.C. supply.

System 18. Single 115V A.C. Supply, 1 Microprocessor, With Adjacency

This system is equivalent to system 16, except the 115V A.C. supply replaces the 28V D.C. supply.

3.1.3 Design Approach

All the eighteen systems described above were dissected into several major design areas.

For the A systems they were:

Dual Photocell U.V. Detectors

28V D.C. Power Supply

Includes stabilization of the input voltage, high voltage inverter and EMC components

115V A.C. Power Supply

Stabilization of the input voltage and EMC components included.

U.V. Detector Drive Circuitry

Isolation of the high voltage U.V. detector drive circuitry enables the effects of increasing the number of detectors to be examined.

Automatic Test Circuitry

Single Microprocessor Approach

This refers to the main signal processing and output control circuitry.

Dual Microprocessor Approach

Hardwire Version of Single Microprocessor Approach

Hardwire Version of Dual Microprocessor Approach

This refers to the main signal processing and output control circuitry.

For the B systems the dissected areas are:

Single Photocell U.V. Detectors

This unit included a test emitter.

Power Supplies

The power supplies were identical to those for System A above.

U.V. Detector Drive Circuitry

Again this circuitry was as the A system.

Single Microprocessor Approach

Hardwire Approach

These latter two areas refer to the signal processing and output control circuitry.

Adjacency Circuitry

In order to ascertain the effects of adjacency on the B system, the adjacency circuitry was separated,

3.1.4 Design Comparison

The concept of the Trade Study was to evaluate the benefi.: of a particular type of fire detection system, and offset these benefits against the cost of that type of system. Within the benefits and the cost sides of the equation that were thus generated there were obviously some sub-divisions each with their own relative merit. Thus, a weighting system for the various features of an individual fire detection system had to be quantified.

In order to compare the impact of different designs of a U.V. advanced fire detection system on life cycle costs and effectiveness, a Trade chart (Figure 3-1) was derived. Weighting factors were allocated which show the order of importance of each item. A high weighting factor means a high importance.

From Figure 3-1 the effectiveness is divided into Fire Detection Ability and Freedom from False Warning.

Once the theoretical circuit design had been derived, each component part was analyzed for its failure rate, for both open and short circuit conditions.

Freedom from false warning is identified as Mean Time Between False Warnings (MTBFW) and is obtained from reliability figures from the electronic design. Thus, all components that go out of tolerance and produce a fire warning have been examined, so producing an MTBFW. These failures are classified as Active failures.

As designs are compared, the Fire Detection ability is a function of the Passive failure rate of the design. That is all components which go out of tolerance, prevent a genuine fire from being indicated.

The life cycle costs can be basically divided into three components; the purchase cost of the system, the physical parameters, such as weight and dimensions, and the Mean Time Between Failures (MTBF)/ Maintenance costs, of the system.

The purchase cost for comparison purposes are obtained in arbitrary units for each design. The method was constant for each design.

The physical parameters were divided into two; size and weight. Again the figures are arbitrary units, with the method constant in each design.

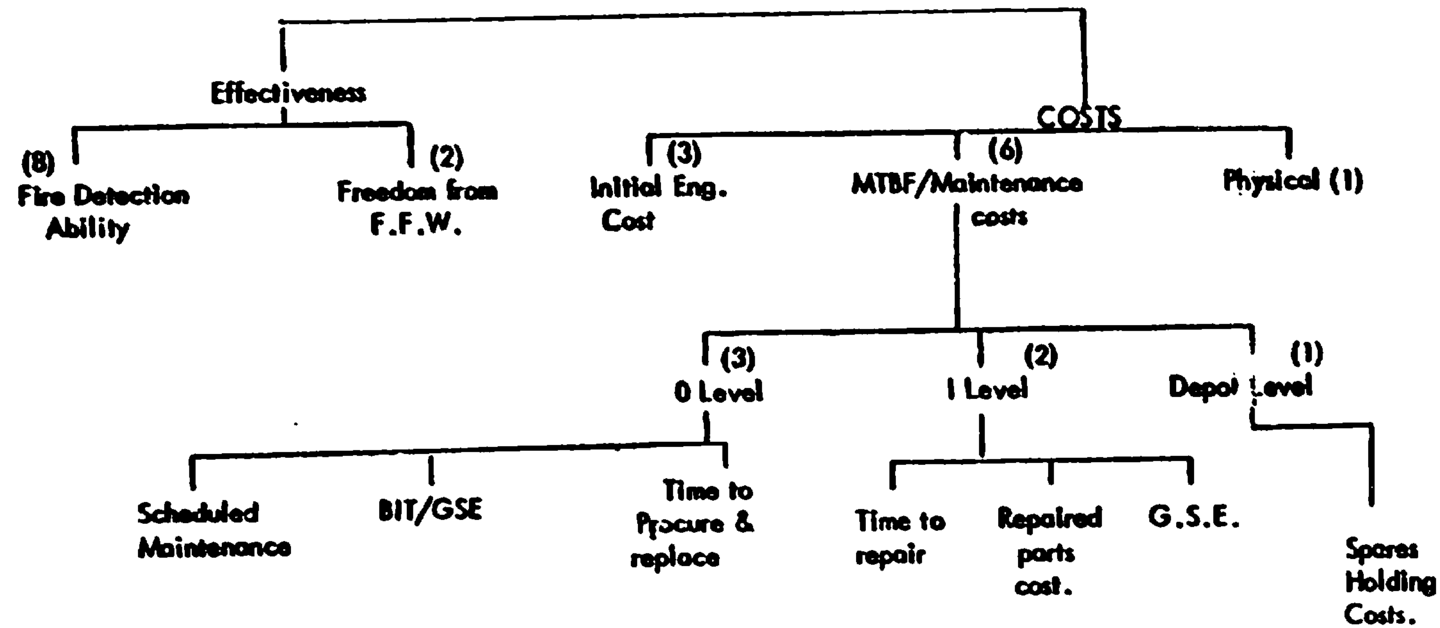


FIGURE 3-1 U.V.A.F.D.S. TRADE OFF PARAMETERS

The MTBF/Maintenance costs can be further divided. However, in order to carry out the study, the MTBF function only was considered, as it was thought that this item was the major influence. Thus, parts of the system going out of tolerance, producing system failures, are summed to produce a reliability figure and hence the MTBF.

With regard to values of weighting factors, it is suggested that the benefits should balance the other parameters, and therefore, if we use a scale of 10, benefits should equal 10. Life cycle costs should equal 10.

The breakdown of benefits is fairly straight forward. It can be argued that the system is not effective as a fire detector if an indication from it does not indicate with a degree of certainty that there is a fire (as opposed to false warning). Looking at the situation from the pilots point of view, therefore, it can be argued that if, when the red light comes on there is less than a 50:50 chance of the red light indicating that a fire exists, the value of the red light is non-existent, and therefore, the equipment is not effective. Thus, the ability to detect fires should be equated equally to the lack of false warnings. (This is entirely in agreement with the requirement that the false warning rate should approach zero, since the frequency of real fire warnings will be very low). However, historical data to hand indicates that in the U.S. Air Force, there is, in fact, a false warning to true warning ratio of 4:1 or worse, i.e. for every time the fire warning light comes on there is a 4 to 1 chance that there is NOT a fire.

Now let us address the sub-division of life cycle cost. It is obvious that the cost of maintenance is a direct function of the MTBF of the system. Thus, for the sake of the Trade Study, it is pointless separating the two items, and a single element MTBF can be used for the purpose of the study. However, since this is a relatively important item, and since it is a prime driver in terms of the cost of ownership of the system, it weighting factors should be high.

The question of ground support equipment and its impact on cost of ownership, was also addressed, however, since the distribution of aircraft using the system is indeterminate, it is not possible to quantify this as an item, and since the overall impact on the cost of ownership is considered to be low, this item was not included in the Trade Study.

The physical make up of the equipment is partly weight and partly size. The impact on life cycle cost of these two parameters is considered to be relatively small, providing that the system size and weight is within the general requirements of the aircraft. However, since some of the options that were investigated have a marked impact on size and weight, the figure of 0.8 for weight and 0.2 for size was left in the Trade Study. Finally, initial system cost obviously has a bearing on the choice of a system, and although it is considered to be a relatively small component of the overall life cycle costs, the initial funding problems it generates suggested a value of 3 should be used.

The resulting equation, therefore, becomes:

U x (Benefits) - (Life Cycle Costs) = Value.

W x (8 x FD + 2 x FW)-(3 x C + 0.8 x W + 0.2 x S + 6 x MTBF) = V.

where

U = Utilization factor.

FD = Failure to detect a fire = passive failure.

FW = False warning = active failure.

C = Cost.

W = Weight.

S = Size.

MTBF = Mean time between failures (See Note 1).

V = Arbitrary value of system (See Note 2).

Note 1

It is recognized that the meantime between failures will appear as part of FD - Failure to detect, and FW- False warning. However, in redundant systems assuming a standard service period, the three functions are not directly related. Since MTBF results in removal costs and replacement costs, the place for MTBF was on the cost side of the equation, while the indirectly related failure modes are shown on the benefits side of the equation.

Note 2

The arbitrary value resulting from this equation is not in itself a measure of the value of a fire detection system on the aircraft. However, it is of value when comparing systems having basically the same function, thus allowing comparison of design methods to be made.

It is recognized that the elements in the life cycle cost bracket, are not all in the same units. Nor are they necessarily correct in terms of real world values on the life cycle of the equipment, and thus, a variety of calculations were carried out on the "winning" systems to measure the sensitivity of the design Trade Off Study to the actual values used. It was found, as a result of these calculations, that the sensitivity to the values was very low. The driving factors were definitely in the benefits area, and because of the functional linking between the passive failure and the active failure modes, even dramatic changes in the ratio of these particular benefits did not effect the outcome of the Trade Study. Similarly, the value applied for utilization factor of the aircraft, had little bearing on the result of the analysis. It is, therefore, believed that the resulting analysis is valid for almost any aircraft in almost any operational mode. This, of course, means that a degree of standardization on aircraft can be achieved.

The assumption made in Note 1 indicates the need for a) a regular maintenance period, and b) ground support equipment. It would only be fair to put the cost of the ground support equipment in the life cycle costs area. However, it is difficult to quantify these costs without an understanding of the logistics of supporting the aircraft in use. Thus, for the sake of this calculation, the element has been left. It is believed that this will not dramatically effect the results of the study.

As the trade off study is by comparison, Figure 3-1 can be broken down into specific items which can be calculated from the design. From the breakdown a Figure of Merit can be obtained. The Figure of Merit for each design can be compared, so that the highest indicates the design with the superior performance.

It should be noted that parameters such as aircraft wiring, immunity to lightning sooting etc. are all assumed constant for each design and as such have no effect in the comparison process.

The results for system A shown in Table 3-1 shows the parameters of each system and a calculated merit figure for each parameter when compared with system 1.

In order to arrive at a figure of merit the following theory was used:

$$\text{Figure of merit per parameter} = \left(\frac{\text{Maximum Parameter Value}}{\text{Minimum Parameter Value}} - 1\right) \times \text{Weighting Factor}$$

The figure of merit is then positive or negative according to whether the compared parameter is better or worse respectively than the initial system parameter.

Thus, a figure of + 2 means that the compared system is twice as good as the initial system. A negative figure means vice versa.

From the total merit figure system 5 is the better system with a value of + 1.2266 when compared with system 1, as against all the remaining A systems which are negative.

The analysis for system B shown in Table 3-2 were carried out in exactly the same manner as for system A.

The results indicate that system 14 is the better system as it has the highest figure of merit at + 6.4197.

3.2 Preferred Systems

As a comparison between systems, the initial system A was compared with the initial system B and found to be 1022 times better.

System 5 was also compared with system 14 and found to be 617 times better. The high relative merit of system 5 is attributable entirely to the high effectiveness in detecting fire, as opposed to false warning or other factors.

In order to evaluate the weighting factors applied to effectiveness, calculations were carried out with the factors to reverse, i.e. Passive failure 2, Active failures 8. The results obtained did not change the order of merit.

Therefore, from this Trade Off Study, the two systems preferred are as follows:

<u>System A</u>

Dual 115V A.C. supply
Dual microprocessor
Eight U.V. dual photocell detectors
Automatic test facilities.

TABLE 3-1
SYSTEM A TRADE OFF STUDY

		Passive Failure	Active Failure	Cost	Weight	Size	MTBF	Total Merit Figure
Weighting (W)		8	2	3	0.8	0.2	6	
System	Parameter Valve (PV)	1.11×10^6	1.515×10^6	104[illegible]	1418	173	1323	
1 Base-line	Merit Figure (MF)	0	0	0	0	0	0	0
2	PV	1968	$.65 \times 10^6$	800	1638	370	1552	
	MF	-4504	-2.66	+.911	-.124	-.227	+1.0385	+1.5985
3	PV	2570	175,131	728	975	166	1950	
	MF	-3447	-15.3	1.2980	.3634	.0084	2.8435	-3457.8
4	PV	2416	$.65 \times 10^6$	770	1538	350	1916	
	MF	-3667.5	-2.66	1.0636	-.067	-.205	2.689	-3666.6
5	PV	1.15×10^6	1.515×10^6	1018	1415	258	1535	
	MF	0.2862	0	0.0736	.0016	-.0982	.9614	+1.2266
6	[illegible]	2430	$.65 \times 10^6$	785	1635	355	1852	
	[illegible]	-3646	-2.66	.9859	-.122	-.210	2.399	-3645.6
7	[illegible]	2929	175,131	693	967	161	.2276	
	MF	-3023.7	-15.3	1.515	.3698	.0149	4.3219	-3042.7
8	PV	2732	$.65 \times 10^6$	735	1530	345	2229	
	MF	-3242	-2.66	1.257	-.0631	-.1988	4.1088	-3239.5
9	PV	3056	1.515×10^6	968	1370	248	1785	
	MF	-2897.7	0	.2324	.028	-.0867	2.0952	-2895.4
10	PV	2667	1.515×10^6	1003	1318	253	1579	
	MF	-3321	0	.1196	.0606	-.092	1.1609	-3319.7
11	PV	66488	175,131	758	1075	186	1574	
	MF	-125.5	-15.3	1.1279	.2552	.0150	1.1383	-138.2
12	PV	66635	175,131	743	1075	171	1884	
	MF	-125.2	-15.3	1.2113	.2582	.0023	2 5442	-186.48

TABLE 3-2
SYSTEM B TRADE OFF STUDY

		Passive Failure	Active Failure	Cost	Weight	Size	MTBF	Total Merit Figure
Weighting		8	2	3	0.8	0.2	6	
System								
13	PV	8551	118,483	123.88	572	99.2	3064	
	MF	0	0	0	0	0	0	0
14	PV	14,590	118,483	141.58	540	94.7	3647	
	MF	5.6498	0	-.4286	.0474	.0095	1.1416	+6.4197
15	PV	7971	151,057	235.3	608	114	3076	
	MF	-.5821	.5498	-2.6982	.0503	.0298	.0234	-2.7872
16	PV	9192	145,772	254.3	618	117	3002	
	MF	.5996	.4606	-3.1583	.0643	.0358	.1239	-2.3221
17	PV	12,977	151,057	253	576	109.5	3664	
	MF	4.1408	.5498	-3.1268	-.0055	-.0207	1.1749	+2.7125
18	PV	11,963	70,422	272	586	1125	3559	
	MF	3.1921	-1.3649	-3.58	-.0195	-.0268	.9693	-.8298
Initial System A No. 1	PV	1.11×10^6	1.515×10^6	1043	1418	173	1323	
	MF	1030	23.57	-22.26	-1.183	-0.143	-7.89	+1022

System B

Single 115V A.C.
Hardwired system
Eight single photocell detectors
Manual test facility
No adjacency.

3.2.1 Final Selection of Systems for Design, Fabrication and Test

Evaluation of additional factors not included in the trade study indicated that, since preferred system A used microprocessors, it would be most advantageous to design System B as essentially one half of System A. This configuration would result in lower costs and still provide the advantages of the System A design. The approach allows commonality of design, components and provides a good baseline for evaluation. The final selection of System A is as by the trade study and System B modified the trade study results and is as follows:

Single 115V A.C. supply
Single microprocessor
Eight single U.V. photocell detectors
Automatic test facilities.

4.0 SYSTEM DESCRIPTION

4.1 System A

4.1.1 General

System A comprises eight UV dual detector heads 53522-011, a computer control unit (CCU) 53813-203 and a crew warning unit (CWU) 53813-202. Physical characteristics are shown in Figures 4-1, 4-2, and 4-3, respectively.

Both systems were designed to meet the requirements of the procurement specification, established under Phase I, and described herein.

The system has been designed to respond to a 5 inch diameter gasoline pan fire at a distance of 4 feet with a response time of one second. However once the fire has been detected, the warning must be retained with only half of the pan fire obscured at the same distance. Thus a hysterisis has been designed into the system to accommodate this part of the specification.

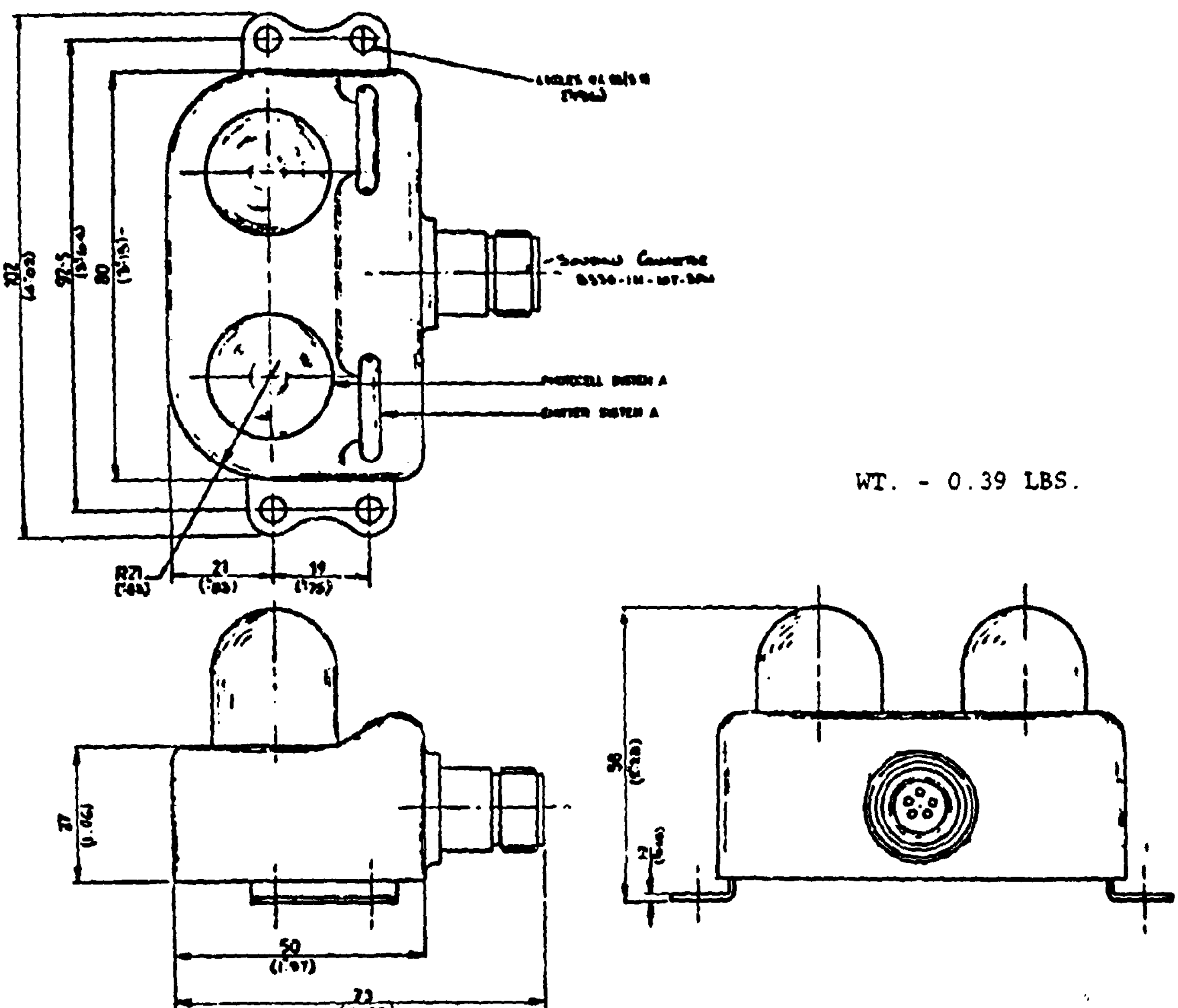
Figure 4-4 shows the complete schematic for System A installation. Up to 8 detector heads may be incorporated in a system, giving ample coverage of hazard conditions in most engine installations.

In the event of a fire, the sensors in the UV detectors respond and feed signals to the Computer Control Unit (CCU), where they are processed by the microprocessor based electronics. The CCU also generates the power for the detector heads.

The system is designed such that there are two channels, each fed by signals from half of the UV detector heads. It is then necessary for both channels to identify a fire warning before an indication is sent to the CWU for display. This is termed 'AND' logic.

The design of the system is such that no single failure of any part affects the fire detection capability of the system, and indeed no visual indication of a fault is indicated even though it is detected internally. In addition, the design allows considerably more system degradation without either losing detection capability or signalling a fault to the cockpit.

Extensive built in test (BIT) facilities have been employed to detect internal failures and switch the offending channel off. Under single failure conditions the AND logic is reconfigured to



WT. - 0.39 LBS.

FIGURE 4-1 UV DETECTOR DUAL HEAD

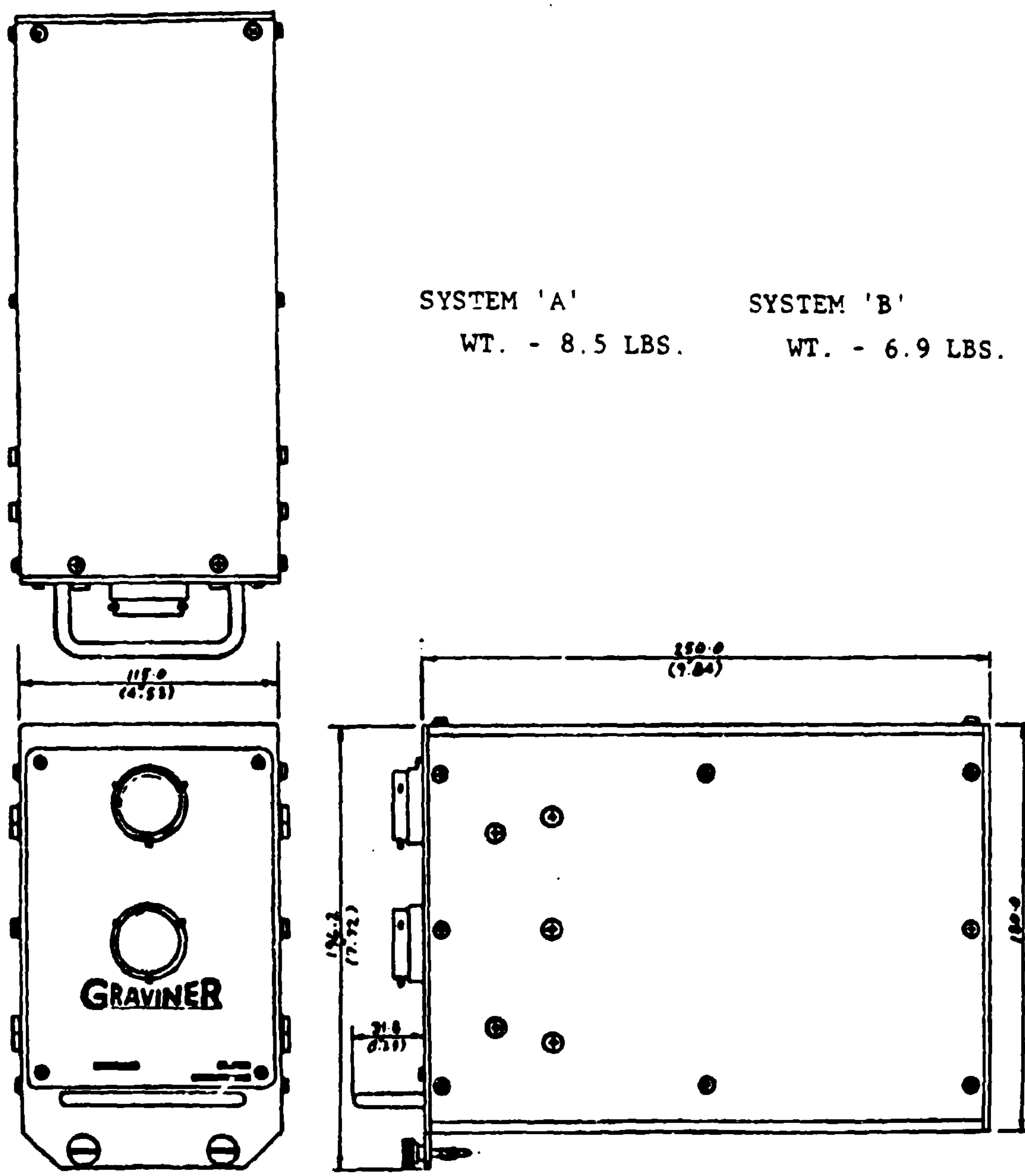


FIGURE 4-2 COMPUTER CONTROL UNIT

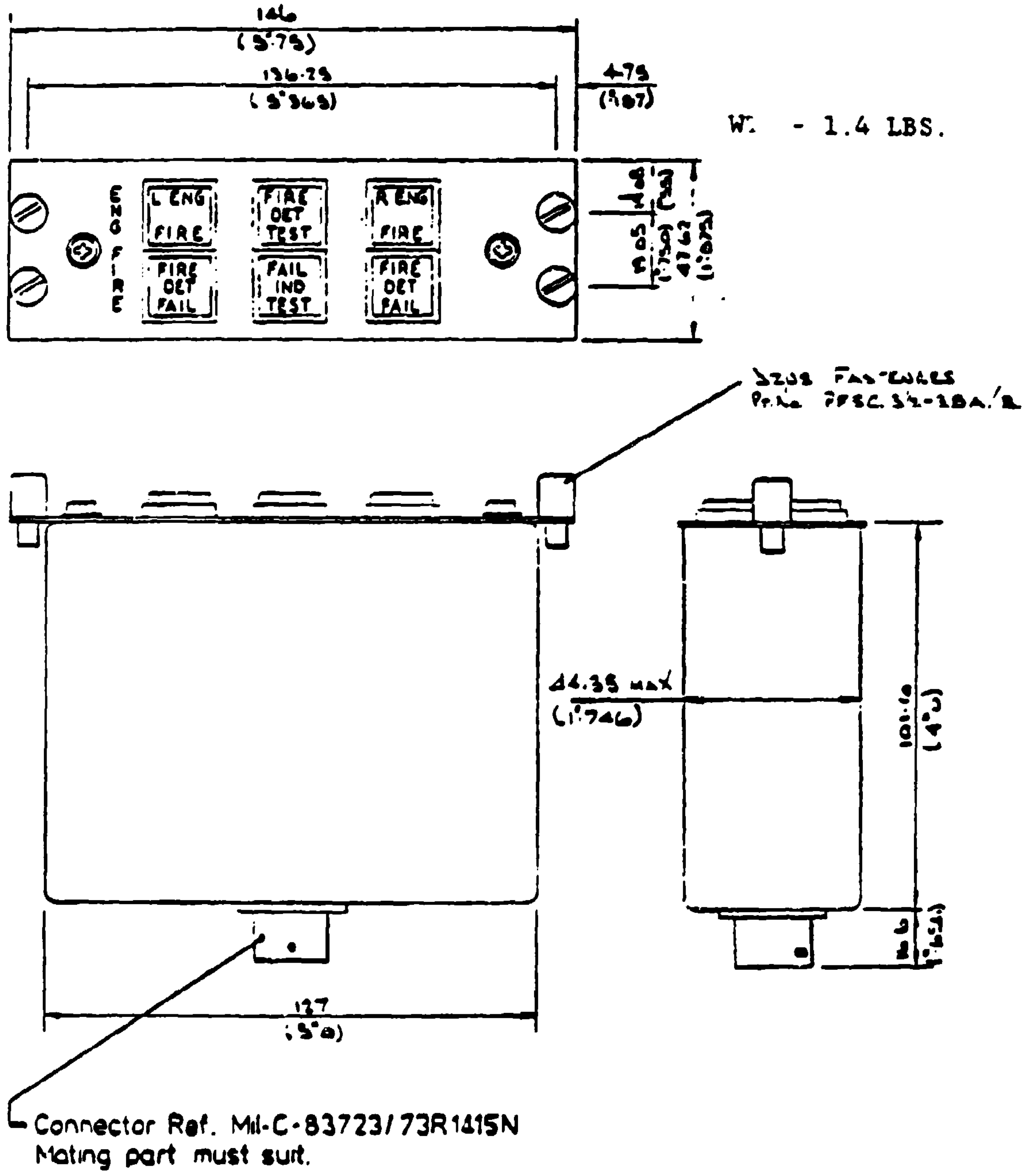


FIGURE 4-3 CREW WARNING UNIT

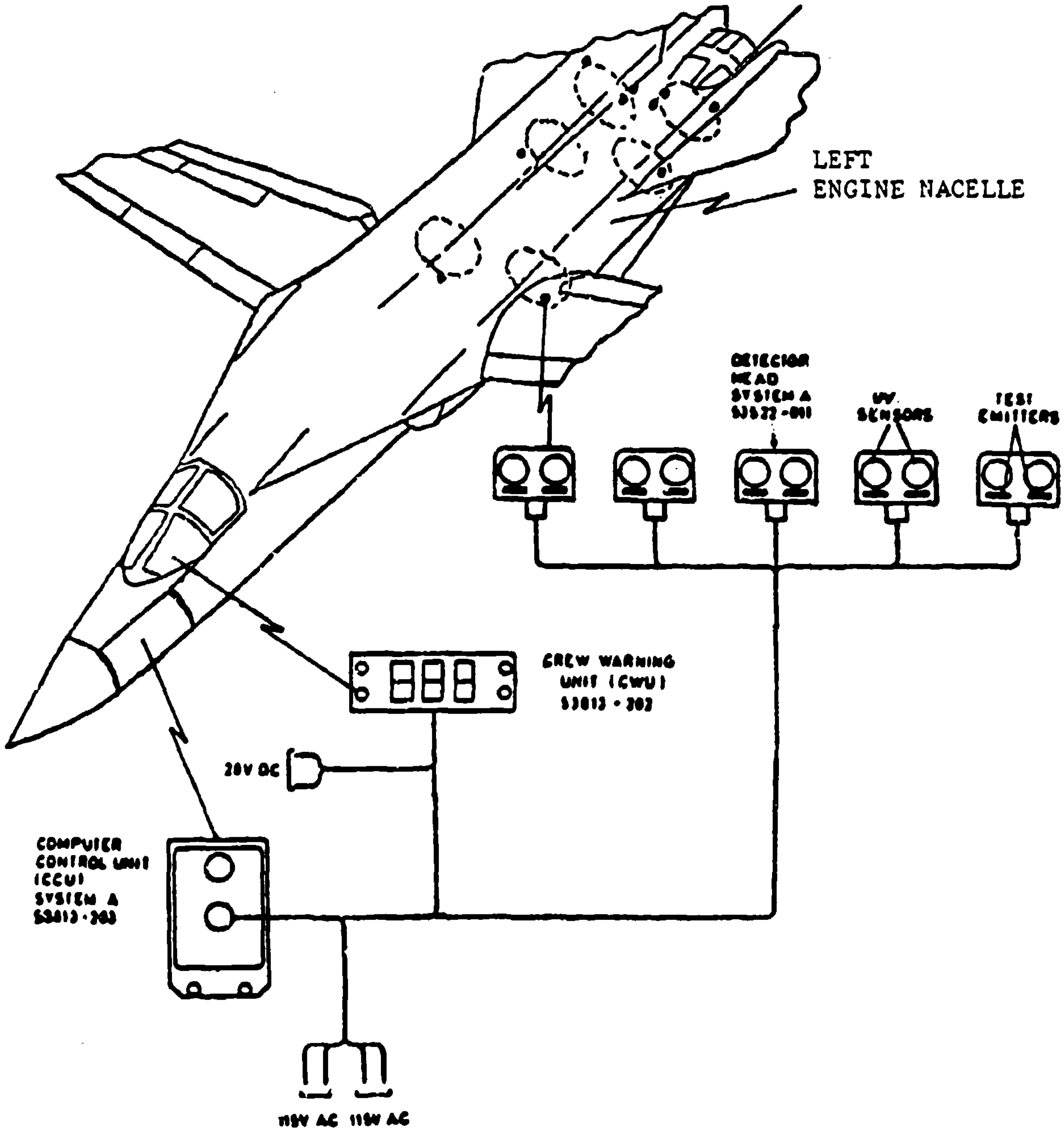


FIGURE 4-4 SYSTEM [illegible] INSTALLATION SCHEMATIC

OR logic allowing the remaining channel to generate a fire warning. The philosophy here is that while the system is still capable of detecting a fire and generating a fire warning, then it should remain in operation. Component failures that do not remove fire detection capability are not signalled to the cockpit but are logged in memory for subsequent identification during maintenance actions. 'OR' logic requires that only one channel is needed to generate a fire warning signal.

When a fault is detected in the system such that a fire cannot be detected or indicated, then a fault output is generated on the CWU, which is mounted in the cockpit.

Verification of the correct function of BIT is provided by manual command tests at the CWU. Two test buttons are employed on the CWU which artificially inject fires and faults into the system, which are processed by the CCU and finally energize the Fire and Fault lights.

Provision for Ground Support Equipment (GSE) has also been made and this is discussed later in Section 4 and VOLUME III.

The following is a general description of the system. A more detailed description of each individual item is given in Section 5.

4.1.2 Detector Head

The detector head has been designed for use either mounted directly on an aircraft engine or in the engine bay area, where ambient temperatures can reach 250°C.

Each detector consists of a plug for easy removal and change, 2 UV sensors and 2 UV emitters; the construction is discussed in Section 5. Physical characteristics are shown in Figure 4-1 and drawing 53522-011, Reference 4-1.

The CCU supplies and controls the 320V D.C. necessary for operation of the sensors and emitters.

Up to eight detector heads can be driven from one CCU, which would provide adequate coverage of hazard areas in most engine installations.

In certain parts of the installation two or more detector heads may view the same area. This is termed adjacency and the CCU checks that all sensors covering a particular area, give a similar output under fire conditions.

It is possible that under very fierce fire conditions, a detector head may be destroyed after it has indicated a fire. If a detector head is mounted in such a hazardous position, then another detector head is mounted such that it also covers the hazardous area. Many combinations of adjacency and redundancy are allowable within the system design and this is discussed in more detail in Volume II of this report.

Each detector head has its sensors supply voltage alternately switched on and off, such that one sensor views while the other sensor is off and vice versa. This reversal occurs every 167 mS.

The sensors in the detector operate in isolation from each other, feeding counts directs to the CCU.

The CCU supplies a test signal to each emitter on the detector head, every 15 seconds. Each emitter when operated emits only enough UV to test its own sensor. Hence every 15 seconds, the CCU can determine how many sensors are functioning and reconfigure itself accordingly.

As an example of this, assume an adjacent pair of detector heads covering one hazard area. In order to generate a fire warning, at least one sensor from each half of the detector heads must detect (i.e.) say detection head 1 has sensors A1 and B1 and the adjacent detector head has sensors A2 and B2. A fire warning is generated only from any one of the following sensor outputs, A1.B1; A1.B2; A2.B1: A2.B2.

If the BIT detects a fault with a sensor say A1 then the system reconfigures to A2.B1; A2.B2 for fire generation. If now B1 becomes faulty then the system reconfigures to A2.B2 only.

Finally, if B2 becomes faulty, then the system will reconfigure so that the output from sensor A2 only would generate a fire warning.

No matter how many detector heads are adjacent, the system will always reconfigure down to the last sensor.
In the event of the last sensor failing, the system will indicate a fault on the CWU.

4.1.3 Computer Control Unit (CCU)

The CCU is designed to be installed in the avionics bay of the aircraft and is the interface control between the UV detector heads and the visual indication on the CWU.

It consists of a box with front mounted plugs and a motherboard/ plug in a card assembly. Physical characteristics are shown in Figure 4-2. Further details are described in Section 5 and drawings for the CCU are 53813-203-GA, 53813-203-ID and 53813-203-CD. The drawings show the size and weight of the unit as well as its installation and circuit diagram. (References 4-2, 4-3, 4-4, respectively.)

The CCU is powered from two 115V 400 Hz aircraft supplies and one 28V D.C. supply.

The CCU contains two CMOS RCA 1802 microprocessor systems each with their own power supplies and controlling one sensor in each dual detector. Thus the two channels of fire detection are isolated except at the fire warning lamp, where they become common.

Each microprocessor passes information to the other so that AND logic can be achieved reliably.

The CCU, every 15 seconds completes a series of tests to ensure the system is capable of detecting and indicating a fire.

The main test routines for each microprocessor, test the detector heads by energizing their emitters; test the output signal paths; test the internal microprocessor program and also tests the opposite microprocessors signalling and processing ability. Using these routines it is possible to ensure that a fire will always be detected unless a fault signal is present on the CWU.

Circuit description and operation is discussed in section 5.

4.1.4 Crew Warning Unit (CWU)

The Crew Warning Unit is designed for use with two engines and can be used with both System A and System B. It is mounted in the cockpit where it gives visual separate indication of Fire and Fault conditions for both engines individually by means of lamps.

One test button is used to check both engine fire systems together. A separate test button checks the fault signalling capability for both engines.

The CWU is powered from the 28V D.C. power supply and 28V signals are derived from the CCU to energize the warning lamps.

The construction and operation is discussed further in Section 5. Details are shown on 53813-202 (Reference 4-5). Figure 4-3 shows the weight and size of the unit.

4.2 System B

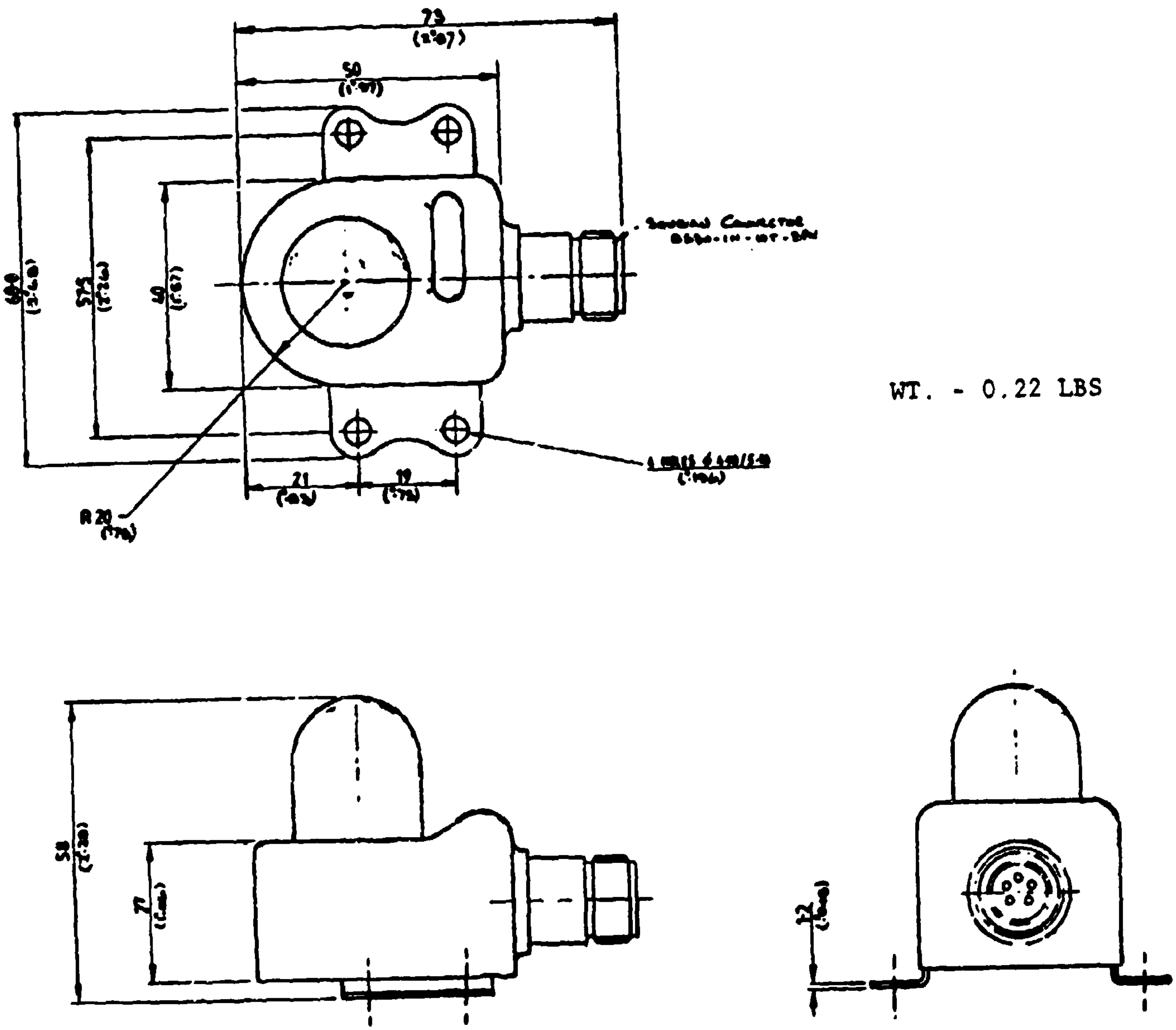
System B comprises eight single sensor UV detector heads 53521-012, a computer control unit (CCU) 53813-204 and utilizes the crew warning unit (CWU) 53813-202. Physical characteristics are shown on Figures 4-5, 4-2, and 4-3, respectively.

Figure 4-6 shows the installation schematic for the system B and comparing with system A, the differences are as follows.

Eight detector heads can be driven from one CCU but the detector heads in system B have only a single sensor and test emitter.

Thus the designed redundancy of system A does not exist and this is reflected through the CCU where only one microprocessor is used for the control.

System B also has adjacency built in as described in section 4.1.2 but obviously is confined to single sensor techniques.
As long as one sensor of an adjacent set is operative the system will respond.
It should be noted that a single detector head failure will only produce a fault indication in the event that it does not belong to an adjacency configuration.



WT. - 0.22 LBS

FIGURE 4-5 UV DETECTOR SINGLE HEAD

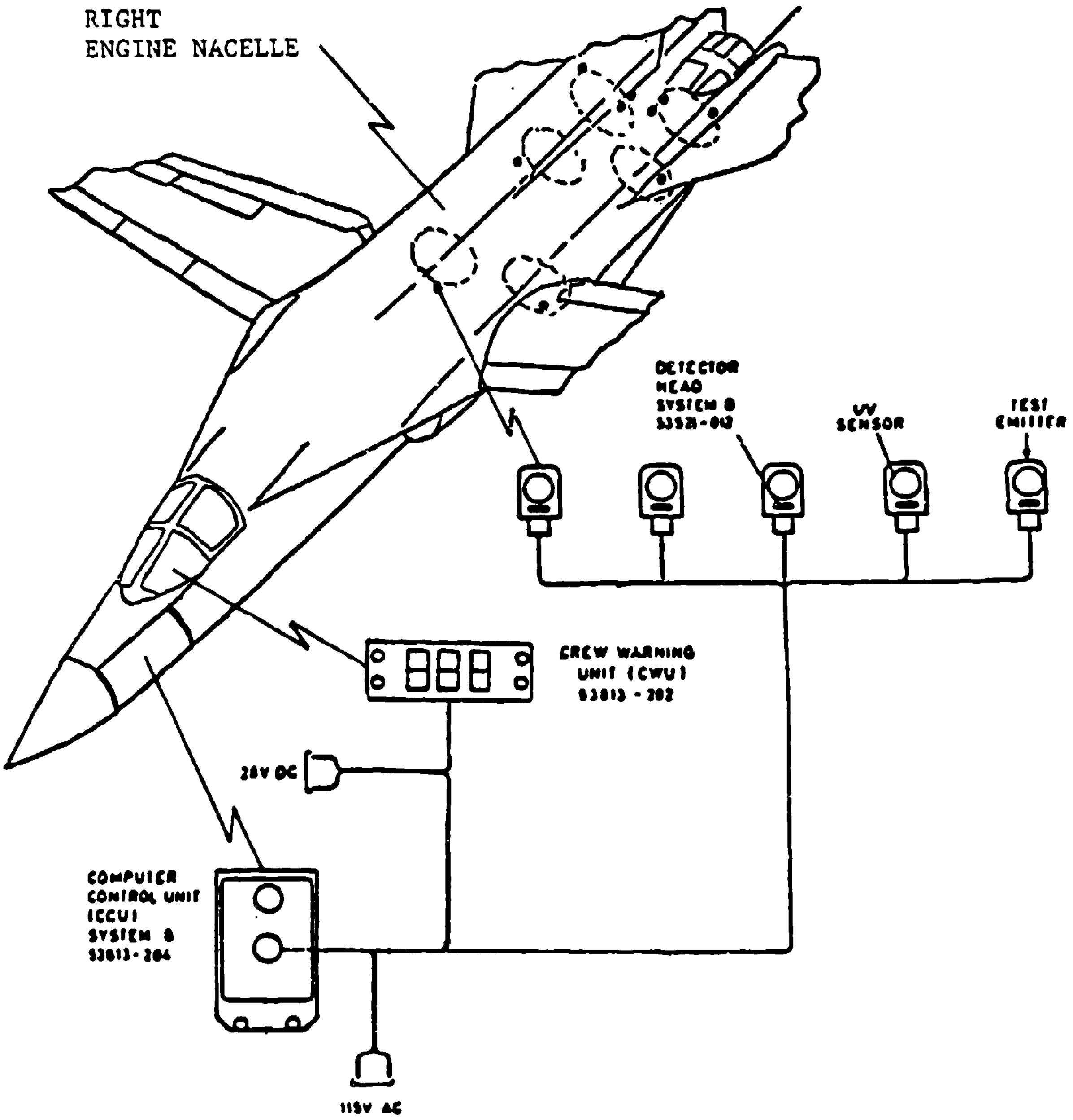


FIGURE 4-6 SYSTEM 'B' INSTALLATION SCHEMATIC

The function of system B approximates to half of system A throughout and can be considered as similar to a system A that has already reconfigured to an OR logic mode, as described in 4.1.1.

Physical dimensions of system B detector head are shown on drawings 53521-012 and system B CCU on drawings 53813-204-GA (References 4-6 and 4-7). The installation and circuit diagram drawings for the CCU are 53813-204-ID and 53813-204-CD (References 4-8 and 4-9).

4.3 Ground Support Equipment (GSE)

The GSE is basically a fault diagnostic maintenance tool and is covered in Volume III.

The GSE identifies only faulty LRU's in the aircraft system, even if these have not been signalled to the CWU. Additional quantitive measurements are also performed by the GSE which permits identification of any trend towards unserviceability.

A further use of the GSE is to extract data from the CCU memory banks on in flight performance of the system. This has been particularly useful during flight testing and has given confidence in the behavior of the system in the absence of cockpit indications.

5.0 COMPONENT DESIGN

5.1 Detectors

The main design constraints of the sensor heads arose from the requirement to use the proven Graviner D6100 UV cell with its associated UV test emitter, to withstand the environmental conditions of a military aircraft engine installation and to be as small and lightweight as possible. Physical characteristics are shown on Figures 4-1 and 4-5.

Within these design constraints the configurations developed and shown on drawings 53522-011 and 53521-012 are probably close to and optimum. (References 4-1 and 4-6.)

The designs are based on the assumption of production quantities that would justify expenditure on tooling for pressed steel case-work but the sensor assemblies used during this program were fabricated without tooling to simulate the proposed production design.

The photocell and protective quartz dome are mounted on a thin steel retainer with a fillet of silicone potting compound. This assembly is then spot welded to the case. In early development samples, some difficulties were experienced with emitter glass envelopes cracking during low temperature tests but this was later overcome by incorporating a resilient rubber compound coating prior to emitter assembly.

The simple mounting base is intended for use with a variety of aircraft brackets which might be necessary to provide appropriate viewing directions in an engine installation.

The assembly meets the required life of 10,000 hours at 250°C with the exception of the electrical connector, which has a life limited by the manufacture to 1000 hours at 250°C.

5.2 Computer Control Unit

System A and System B electronic circuitry is contained in mechanically identical racking. General Assembly drawings 53813-203 and 53813-204 show pictorially the systems' con-truction. (References 4-2 and 4-7.) Physical characteristics are shown on Figure 4-2.

The essential features of both systems are as follows:

a) It is a box construction consisting of formed top, bottom and side panels, with two similar cast end plates. The rear panel has on its external face indented locating slots to ensure correct positioning of the units in the aircraft racking and on its internal face it contains guides to ensure location and adequate fixing for the printed circuit boards.

The front panel has mounted through it, two captive knurl headed screws to provide fixing to the aircraft racking. Two circular electrical multipin connectors are mounted through the front panel. One, termed on the front panel label the 'aircraft plug', routes to the electronics power and signals from detectors and also carries the signals to the crew warning unit (CWU). The second connector, termed the GSE plug, is utilized when the system is inter-rogated by ground support equipment and is not normally used when the aircraft is operational.

Internally, the box contains a cross member which acts to make the construction more rigid. To this are attached the printed circuit board guides.

b) Within the box a mother board printed circuit card acts to connect the various parts of the control unit electronics together. On the mother board are mounted connectors which mate with the cable harness connected to the two circular connectors, and to the daughter board connectors. The mother board also houses the transformer for the systems' power supply requirements.

c) A filter board is mounted on the front panel, close to the aircraft plug such that incoming power can be filtered.

d) The printed circuit cards contained within the units are interconnected via the mother board, and consist of, in the case of System A, a common logic card, two microprocessor cards, two head drive cards, a master logic card and a slave logic card. In the case of System B, the unit contains a common logic card, a microprocessor card, a head drive card, a master logic card and a battery card which is braced such that the mass of batteries does not cause vibration problems. Each card edge connector is polarized such that boards cannot be incorrectly located within the boxes.

5.3 Circuit Description

A block diagram of the CCU is shown in Figure 5-1. This is shown to give a general appreciation of the way the CCU printed boards interface with each other. Circuit description is essentially on a board by board basis. Reference is made to the CCU circuit diagram 53813-203CD (System A) or 53813-204CD (System B), for a clearer understanding of the way cards are interconnected. (References 4-4 and 4-9.) Detail description of the circuit design can be found in Volume II.

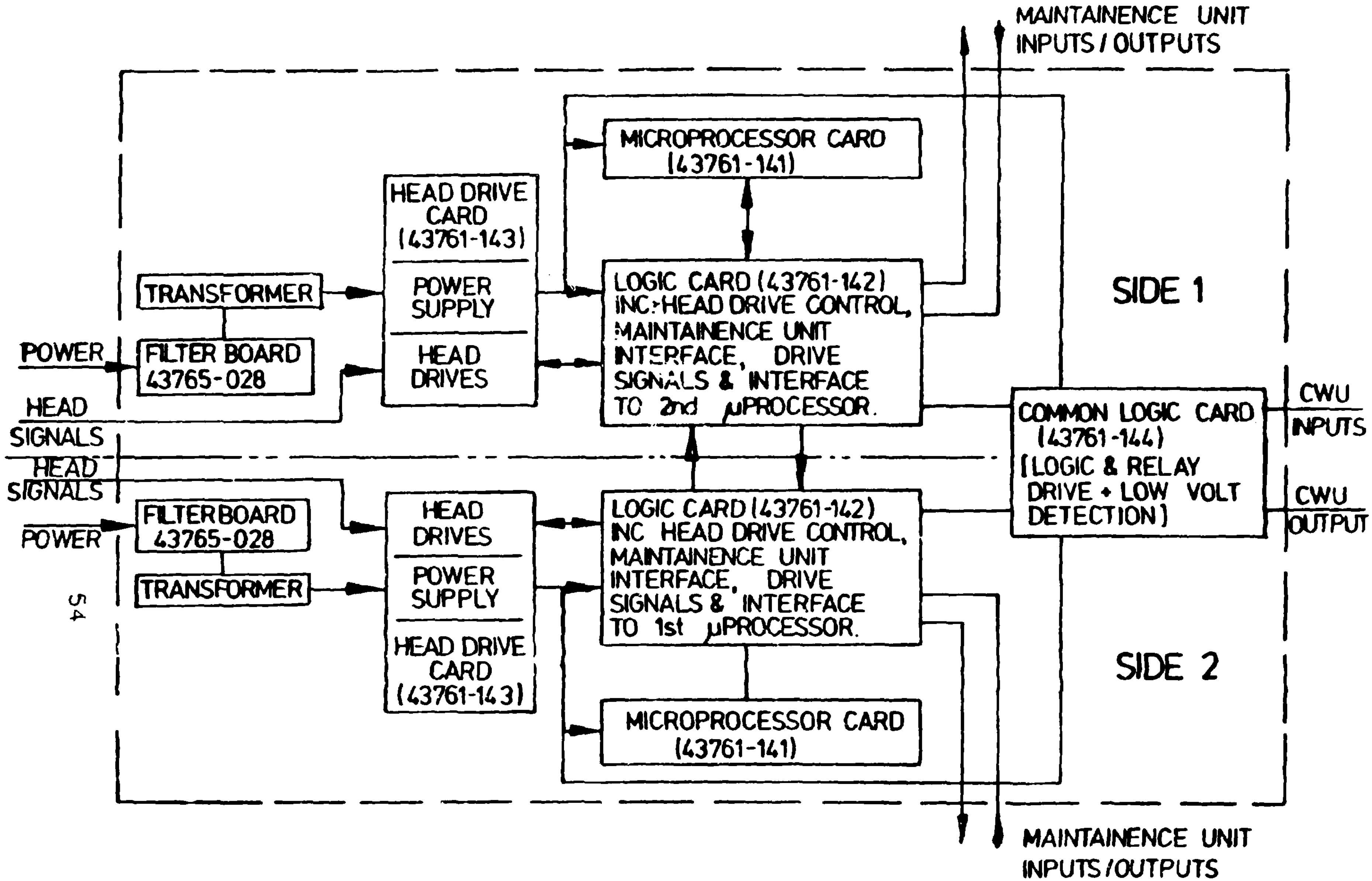


FIGURE 5-1 COMPUTER CONTROL UNIT BLOCK DIAGRAM

6.0 SOFTWARE DESIGN

6.1 Overview of Software

The system software resident in 3K bytes of ROM memory serves to control timing functions of the system, to process and act on fire data and to effect many system tests designed to prove the integrity of the system.

The assembled program listings are contained in Volume II, all software description refers to the relevant program and should be read in conjunction with the system flow diagram 53813-203 and 204 FD. (Reference 6-1.)

Program structure is such that the majority of functions occur under interrupt control due to the time dependent nature of the system requirements.

6.1.1 Software Component Programs

A cyclic operation occurs after the INITIALIZATION program has been completed, in which the two sides of the system (if System A) are synchronized and all required registers and memory locations are set to initial values.

After initialization the BACKGROUND program is entered, the primary function of which is to carry out tests to provide that ROM memory is not corrupt. This program is interrupted at intervals of 832 us to carry out the INTERRUPT program.

The interrupt program has two phases, GATHER and PROCESS, both are responsible for system timing. During the gather phase the sides time share is high and at each interrupt event the main function is to obtain head data. This phase lasts for 167ms.

On completion of the gather phase the time share changes to a low level and the PROCESS phase commences, this also lasts for 167ms.

At each interrupt event during the process phase, system timing and system interrupts are monitored.

The FIRE program is responsible for processing the head data and computing if a fire or fault condition is to be set or reset. The fire program is executed after the gather phase of the interrupt program and is entered from the background program. Consequently the fire program is interrupted every 832 us meanwhile background operation is suspended. Upon fire program completion background operation resumes.

The final major element of the software is the GSE program which is executed upon command of the remote test equipment.

6.1.2 Program Development

All programs were edited and assembled using an RCA develoooment system apart from the fire program and parts of the GSE program which were compiled using a tie to a main frame computer.

Main frame written program was debugged in the same medium and then combined with the remaining program which was then debugged using the RCA development system and associated emulator. A more detailed discussion of the software segments can be found in Volume II.

7.0 FLICHT TEST

Flight tests were conducted on a General Dynamics FB-111A. The aircraft was made available at McClellan AFB, Sacramento, California where installation and flight testing of the fire detection system took place.

Reprèsentatives of General Dynamics and Graviner supported installation and initial flight trials.

7.1 Flight Test Plan

The requirements, aims and methods of flight tests are contained in Appendix A-1.

7.2 Installation

7.2.1 Commissioning Prior to Engine Installation

System installation was carried out in accordance with installation drawing Z22004 (Reference 7-1). All wiring and mounting hardware was installed by technical personnel of McClellan AFB.

The aircraft wiring was checked against the installation drawing ensuring that all screening of cables was correctly carried out. A deviation noted was that the method used to pass cables through the engine fire wall caused all head screens to be jointed together. On the non engine side of the fire wall the screened cable was again commoned together at the fire wall connector and, as per installation drawings, at the CCU. This configuration formed a potential earth loop path, however due to the shortage of pins in the fire wall connector no alternative was available.

Prior to installation in the empty engine nacelles the heads were checked out in conjunction with ground support equipment. The CCU s A and B and CWU were then installed in the aircraft instrumentation bay and cockpit respectively. Siting of the units is depicted in Figures 3 and 4 of Appendix A-1.

With ground power applied to the aircraft the system was switched on by closing the four system circuit breakers located in the instrumentation bay.
Initial system checks were carried out by observing that all emitters struck at regular 15 second periods. The FIRE DETECT TEST button of the CWU was depressed and fire indication of the LEFT ENG FIRE and RIGHT ENG FIRE was observed. In this mode all heads were viewed to ensure that all emitters flashing in sympathy with the time share period

The FAULT INDICATION TEST button of the CWU was depressed and fault indication of the left and right FIRE DETECT FAIL indicators was noted.

Fire conditions were simulated with a UV light source termed a 'wand'. The system proved to respond correctly to the UV light source.

Further confirmation of correct operation was then carried out using the ground support equipment.

Initial attempts to connect the GSE according to the method laid down proved unsuccessful.

Connection method was to mate cable 1 of the GSE to the GSE connector on the CCU to be tested prior to disconnection of the aircraft harness from the CCU. The aircraft harness was then to be mated to cable 2 of the GSE and the CCU aircraft plug to cable 3. The whole operation was carried out without removing power from the system by breaking the contactors.

It was found that this technique caused random corruption of RAM memory locations, a phenomenon not observed when system tests were conducted at place of manufacture.

Due to the specialized nature of test equipment required to investigate the fault, the cause was not discovered. However the solution was to modify the method of connection.

By initially removing power by pulling first 28V and then 115V circuit breakers before performing the connection procedure nc loss of memory occurred.

Tests were then performed to prove that the GSE would analyze head data correctly. Each head was separately stimulated with a fire condition from the UV wand, at the same time all other heads were screened from viewing the fire source. For each head, correct identification (by fire area) was observed at the GSE. Data and time of event was issued correctly.

The system was then caused to fail by removing heads, one adjacency set at a time. The system was observed to fail correctly by indication on the relevant CWU fault lamp. Ground support equipment was then used to prove correct identification of the area of failed fire cover.

7.2.2 Commissioning With Engine Installed

The first attempt to install engines showed that it was necessary to relocate heads at the 770 frame to ensure that fouling of heads by the engine did not occur.

It was noted at this time that the orientation of the detectors at the rear of the engine nacelle was not ideal. Position of heads 4 and 5 were observed to be such that the most sensitive viewing segment of the detector electrodes was in line with the after burner plume.

With the engines installed the systems correct operation was confirmed with GSE and by performing tests with the UV wand.

Representatives of General Dynamics then carried out EMC tests in accordance with the requirements of the Flight Test Plan of Appendix A-1.

7.2.3 Commissioning With Engine Running

Initial engine runs with reheat showed that the heads were responding to the UV content of the afterburner plume.

Data obtained from connection of the GSE showed that Area 3 (the area rear of the 770 frame) was responsible for the fire indication. Appendix A-2 contains data readouts obtained during the flight trials period.

Figure 1 of Appendix A-2 shows the readout from System B immediately after the engine run. Data analysis showing that a single fire event in area 3 was logged. System A however did not issue a fire condition although data readout did show that area 3 heads responded to the afterburner.

To overcome this it was necessary to shield the heads, i.e. to restrict their field of view. It was difficult to gain access to effect shielding of the responsible heads with the engine in place. General Dynamics personnel made the decision to disconnect the left and right inboard area 3 head because access to it was impossible. Head 5 disconnection was performed by removing appropriate cables at the aircraft plugs.

Head 4 shielding was accomplished by painting the glass domes of the sensors with black paint so that the electrodes were only viewing the fire area. A check was then carried out with the UV wand to prove that the afterburner plume was not visible to the detectors but that the fire area was.

Figure 2 of Appendix A-2 shows data analysis of system B subsequent to the third engine run which proved that no response to the afterburner occurred. During this run the stabilizers were rotated to check that reflections of the plume were not incident on the detector.

7.3 Failure of Heads

Immediately after engine tests it was observed that there was a tendancy for heads to fail on the periodic self test sequence. This was shown by GSE readouts, a typical example is shown in Appendix A-2. Figure 3. The data circled shows a failure of head 2. It was observed that the tendancy for failure occurred when the aircraft was first powered-up each day. After resetting the fault with ground support equipment no further re-occurrence of head failure was noted until after the system had remained off for a few hours.

Because the fault was resettable, flight trials were carried out by resetting the system with GSE immediately before a flight. An investigation into the cause of failure is discussed in Section 7.5.

7.4 Dedicated Flight Trials

7.4.1 Flight 1

The first flight was carried out on 9 September, 1980 during which the aircraft attained an altitude of 46000 feet and an air speed of MACH 2.05. Appendix A-2. Figure 4 shows data read out of Systems A and B after the flight. A GSE readout was not available at this time as the failures of 7.3 were thought to be associated with attaching the readout equipment.

Analysis of the data shows that all heads remained functional throughout the flight, no fire conditions were logged and no head strikes were recorded. Total duration of system operation was approximately three and a half hours.

Aircrew reported correct response to CWU tests and no indication of fire or fault conditions throughout the flight. It was noted that this flight was more severe than the requirement of the first flight laid down in Appendix A-1.

7.4.2 Flights 2 and 3

Flights 2 and 3 of Appendix A-1. were combined into one sortie.

Data from the flight carried out on 11 September 1980, is shown in Figure 5 of Appendix A-2.

Note: That both A and B systems correctly declare the disconnected head number 5 as faulty.

The flight data shows that no fire or fault conditions were logged during flight and that no heads failed.

System B was noted to have had one gate time filled as defined by a count of 1 at level 1 in the Flight Data section.

Aircrew reported correct response to CWU tests and no indication of fire or fault conditions throughout the flight.

7.4.3 <u>Flight 4</u>

The fourth flight of Appendix A-1. attained a height of 40,500 feet and a maximum airspeed of MACH 2.15.

Figure 6 of Appendix A-2. is data obtained from the flight.

Data readout and aircrew response proved that the system performed correctly.

It is noted that System B recorded 5 gates filled during the flight, while side 2 of System A recorded 1 gate filled.

7.4.4 <u>Nacelle Temperature Data</u>

For flight trials, McClellan AFB technicians installed a temperature monitoring system such that a temperature/time plot of ambient temperature at each head could be recorded and subsequently analyzed. Appendix A-3. contains the temperature data obtained from flight 3.

From the data it was observed that the highest temperature occurred at head 3 of System B recording 310°F. This temperature was attained while the aircraft was running afterburner at MACH 2.15 for an extended period of time.

7.4.5 <u>Non Dedicated Flights</u>

Flights made subsequent to the dedicated flights of Section 7.4 were not attended by Graviner personnel.

The following is a summary of all flights carried out during the period September 1980 to April 1981.

FLIGHT TEST TIME ON FB-111A N01 (67-159)

FIRST FLIGHT 9th SEPTEMBER, 1980
DEDICATED FLIGHTS COMPLETED 12th SEPTEMBER, 1980

1980			
SEPT.	3 SORTIES	5.4 HOURS	1 FLT.M2 at 46K FT. 1 FLT.M2 at 40k.FT. 1 FLT. SUBSONIC
OCT.- DEC.	10 SORTIES	13.9 HOURS	SUBSONIC
1981			
JAN.- FEB.	3 SORTIES	8.7 "OURS	SUBSONIC LAST FLIGHT IN FEBRUARY WAS IN A/B FOR 45 MIN. at MACH.94
MARCH	2 SORTIES	4.0 HOURS	SUBSONIC
APRIL	2 SORTIES	1.6 HOURS	SUBSONIC
	20 SORTIES	33.6 HOURS	

NOTE: (1) A/B USED ON ALL FLIGHT TAKE OFFS.

(2) UV FIRE DETECTION SYSTEM IS OPERATIONAL EVERY TIME AIRCRAFT GROUND POWER IS TURNED ON. IT IS ESTIMATED THAT THE UV FIRE DETECTION SYSTEM HAS IN EXCESS OF 350 HOURS OF OPERATION FROM SEPTEMBER, 1980 THROUGH APRIL, 1981

7.4.6 Problems Encountered During Flight Test

The following is a summary of problems encountered during the flight test period September, 1980 to April,1981.

PROBLEM	CAUSE AND RESOLUTION
On initial system installation fire warning light on during ground A/B operation.	o UV radiation from A/B plume triggered warning light on. o Mask field of view of detector tube from UV radiation reflections.
Fire warning light on approximately 5 seconds during flight 16 when coming out of A/B.	o (1) Found paint peeled off mounting hole cover leaving shiny surface. o (2) Paint flaked off in mask area of tube. Believe UV radiation reflections cause of fire warning light. o Painted cover and retouched mask area. o Normal operation on last 4 flights.
Random fail light during aircraft ground power-up. No occurrences in flight.	o Reluctance of the automatic test emitter to fire after and extended off period (see Section 7.5). o Added reset function to CWU test button in Crew Station (see Section 7.6).

7.5 Fault Investigation

The failure of some heads (randomly) to respond to emitters was initially investigated remotely by requesting AFB technicians to perform tests that might reveal the cause. Simultaneously, at Graviner, tests were performed on an equivalent installation. However, the observed fault was not duplicated.

Subsequently, a visit by Graviner representatives was arranged and Appendix A-4. contains the report of investigations carried out.

7.6 Modification Resulting from Flight Trials

Paragraph 3.3. of Appendix A-4. proposed a procedure to reset the system memory. This modification is discussed in Appendix A-5.

7.6.1 Description

The wiring requirements of the modification and the relevant associated circuits is shown in Figure 7.1.

With the GSE input line 3 tied to zero, the program code at the proce· ›r (when an input on port 6 is executed) instructs the micro-proce : to carry out the subroutine RAM RETENTION (PART A), see Volume ıI. This will only occur if GSE input line 4 has been pulled low (the input which determines whether a fire program of GSE program is to be run).

If during flight either the fire test or the fault test buttons are separately pressed, no effect on the system operation occurs. Pressing the fire test button connects a reverse biased diode to the GSE 3 and 4 input lines pull up resistors. If the fault test button is pressed after power up, the program has passed the point at which it looks at the GSE input lines to determine which program is to be run.

If the fire button is depressed and held followed by a depression of the fault button a zero return path for the diode D6 now exists and the capacitors C1 are discharged resulting in the logic card CLR (NOT) line being set to reset state.

If the fire button is released and the fault switch still held the reset condition is removed and system program operation begins at H'0000'. This causes port 3 to be read resulting in the execution of program RAM retention part A.

With the fault button still depressed the fire button is again depressed causing a second reset.

Releasing the fault button and subsequently the fire button starts execution at memory location H'0000'.

This time the system will, due to coding on input port 3, execute the fire detection program. When interrogating memory locations 0C01 and 0C03 the identity A5,A5,A5, is not observed because the GSE program caused it to be set to 01,02,03. Therefore, as described in Volume II a memory reset occurs, thus removing any faulty head identification from memory location 0CC5.

The sequence therefore provided a simple method of reset from the cockpit station to enable flight testing to continue gathering performance information.

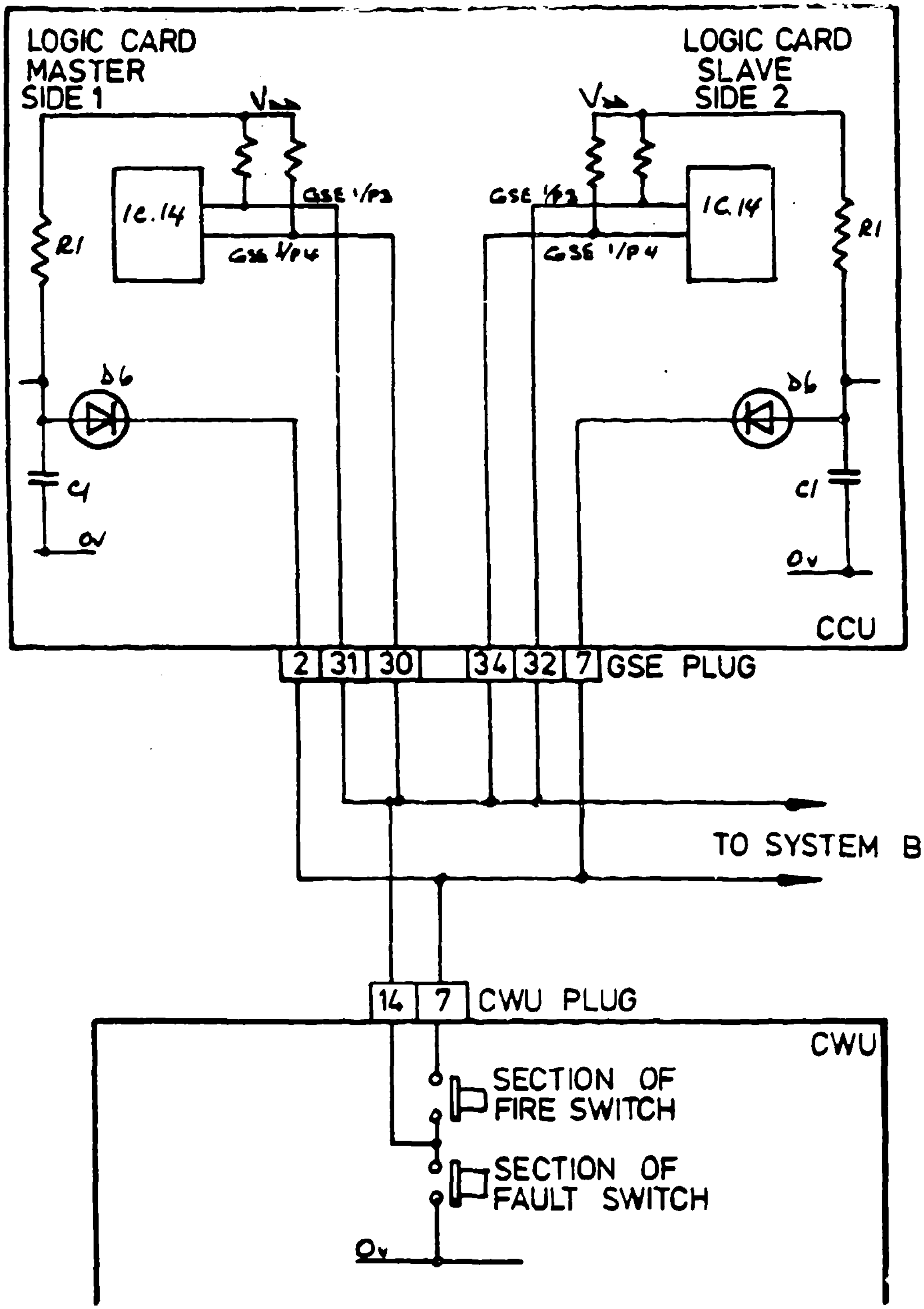


FIGURE 7-1 SYSTEM RESET MODIFICATION

8.0 ITEMS TO BE RESOLVED

During this program some items arose which are either not fully resolved or at least merit further consideration in relation to any future installation. These are identified as follows:

8.1 FAIL/FIRE Precedence

The original SOW is anomalous in that a para. 1.3.2.2. it is stated that a FAIL warning shall override a FIRE warning except in the case where a FIRE warning is given first. The practical significance of this in the program relates to the manner in which the test emitter lines are driven. In order to meet the requirements of SOW para. 1.4.1.3. (Exposure to Flame), it is necessary to ensure that grounding of an emitter drive wire in the sensor immersed in flame does not inhibit emitter tests on other sensor heads, otherwise the system will properly determine a FAULT mode and override the FIRE signal. It is relatively easy to guard against this by either driving emitter lines separately or through resistors to ensure that single emitter grounding does not disable other emitter drive leads.

In the flight test installation on FB-111A this degree of separation was not incorporated. For any further installation it is suggested that the trade-off of system wiring weight, desired operational mode and EMC testing may need further consideration.

8.2 Emitter Start up

In the flight test program a problem was experienced of emitters being reluctant to strike after a long 'off' period. In subsequent investigation it was determined that almost any radiation on the emitter, from visible indication to a radioactive source, is sufficient to prevent the phenomenon. On the flight test system the problem was circumvented by providing a simple cockpit reset procedure but this would not be acceptable in future production systems.

The preferred solution is to add a trace of radioactive gas to the low pressure gas fitting of the test emitters. No problems are seen in implementing this modification but it is not yet tried.

Alternative less prefered solutions are on initial higher electrode voltage to ensure starting in the absence of radiation or an external radioactive source.

8.3 Detector Guards

No breakage of UV cells or quartz protective domes was experienced during the program. Nevertheless, it was apparent during system installation on the aircraft that other equipment, and cableforms could impact sensors during maintenance operations. It is recommended that consideration is given to protective metal guards on any service system.

9.0 DEVELOPMENTAL POTENTIAL

The System as fitted to the F-111 has proved to be entirely satisfactory with regard to the key parameters set out in the original program objectives which were an extremely low false alarm risk and a high probability of sensing a fire.

Both these parameters have been demonstrated

A) By the actual flight test program, whereby no false alarms have been detected.

B) By recovering information on the Ground Support Equipment which determines that there is adequate margin of safety between the current operating conditions and the fire detection levels.

C) By the inadvertant use of the afterburner system in an area that allowed reflection of the flame image to be seen by some of the tubes which promptly gave a fire warning, thereby demonstrating the capability of responding to a true fire situation.

D) By Design calculations based on the measured performance of UV sensors to fires and other unwanted signal sources.

Against this background of success as a rapid response fire detection system, further potential for the development of the equipment is examined under the following main headings:

* Cost Reduction of UV Fire Detection System.
* Combined Fire and Overheat Detection.
* Other applications.

9.1 Cost Reduction

In the areas of cost reduction, three factors operate in favor of further development of this system, namely:

Hardware development.
Volume production.
Removal of development data requirements.

9.1.1 Hardware Development

The cost of hardware used on this program has already been reduced during the two year span since original hardware was specified.

This is the continuing impact of the development of the micro-processor industry, thus any production system specified even if the requirements were identical, would be reduced in cost.

9.1.2 Production Volume

The prototype equipment of necessity employed discrete components in many areas where if a reasonable production run was forecast, adequate tooling and dedicated circuit design would allow for reduction of component count with some substantial side benefits. For example:

* The reduction in the number of circuit boards in the system.

* Reduction in the overall volume of the system.

* Reduction in the power requirements for the system.

It is estimated that a series production CCU can be reduced to one quarter the volume and less than one half the weight of units used in this program

9.1.3 Removal of Development Data Requirements

For production use, much of the data collection facilities that were made available both in the Ground Support Equipment and on the flight hardware would not be needed. This would impact the quantity of hardware to be carried with the above mentioned side benefits. A minimum display can be envisaged which would simply identify a faulty LRU for maintenance personnel.

The retention of flight test data made it necessary to incorporate batteries to maintain power on the memory during the time the aircraft power is turned off and the data is extracted from the memory. A non volitile RAM, being developed during the design period was not available and consequently the battery power was required. For production any data retention could be accomplished with a non volitile RAM.

9.1.4 Combined Fire and Overheat Detection

A significant advance made in this program has been the application of a microprocessor based control unit to an aircraft fire detection system. The capabilities of the microprocessor system are that it can handle readily large amounts of input data, can provide logical interpretation of that data and can provide a variety of outputs (Alarms, Fault indications, Maintenance data).

The same capabilities that have been applied to the fire hazard apply equally well to the hot gas leak or overheat hazard. The overheat hazard may well have an occurrence rate 4 or 5 times greater than the fire occurrence rate on military aircraft engines, but, if accurately identified, does not necessitate the same emergency actions. As noted above, the UVAFDS provides accurate identification of the fire conditions. The microprocessor control unit is well able to handle other input data which may be derived from a continuous cable type sensing system and the unit can interpret the data to provide separate fire and overheat alarm outputs.

The combined system is therefore considered to be a logical next step in the development of improved hazard protection systems.

9.1.5 Other Applications

Other applications of this system which might be considered in further studies are listed as follows:

* Analysis of in flight trends - Analog data logged particularly from cable sensor systems can provide an engine condition monitor.

* Advanced Maintenance planning - The re-configuration decisions made in a system containing such a large degree of redundancy can provide advanced planning data for maintenance actions.

* Battle damage management - Several links are possible between the subject system and aspects of the battle damage situation. These include detection of attack induced fires, deployment of suppression means without pilot intervention, addition of other emergency equipment to the microprocessor test routines and links with fuel management systems.

10.0 CONCLUSIONS

The objectives of this program have been met. A UV fire detection system has been developed, fabricated and test flown on a high performance aircraft. The system has a fire detection reliability and a freedom from false warnings which is significantly better than any existing service equipment. A high degree of redundancy, self checking and automatic reconfiguration is built into the system providing both a reduction in pilot work load and reduction in unscheduled maintenance actions. The system is considered suitable for near-term service applications.

The initial cost of the new system is estimated as being 2.5 times present systems but the total life cycle cost as 0.4 or less.

A logical development of the new system is seen to be in the incorporation of overheat signalling, where similar reliability improvements can be made at low technical risk.

REFERENCES

2-1 Berger, K, Anderson, R, B., Kroninger; "Parameters of Lightning Flashes"; Paper, Electra (France) July 1975

4-1 Graviner Ltd. Drawing; UV Detector Dual Head; No. 53522-011-I.D., Rev. H

4-2 Graviner Ltd. Drawing; Control Unit for Ultra-Violet Advanced Fire Detection System, System A; No. 53813-203GA, Rev. E

4-3 Graviner Ltd. Drawing; Computer Control Unit, System A; No. 53813-203-ID, Rev. F

4-4 Graviner Ltd. Drawing; Circuit Diagram for Ultra Violet Advanced Fire Detection System A; No. 53813-203-CD, Rev. A

4-5 Graviner Ltd. Drawing; Crew Warning Unit; No. 53813-202-ID, Rev. G

4-6 Graviner Ltd. Drawing; UV Detector I.D. (Single Head); No. 53521-012-ID, Rev. H

4-7 Graviner Ltd. Drawing; Control Unit for Ultra Violet Advanced Fire Detection System, System B; No. 53813-204GA, REv. E

4-8 Graviner Ltd. Drawing; Computer Control Unit, System B; No. 53813-204-I.D., Rev. F

4-9 Graviner Ltd. Drawing; Circuit Diagram for Ultra Violet Advanced Fire Detection System B; No. 53813-204-CD, Rev. A

6-1 Graviner Ltd. Drawing; Flow Diagram for Ultra Violet Advanced Fire Detection System; No. 53813-203/204-F.D., Rev. B

7-1 Graviner Ltd. Drawing; Advanced Fire Detection System Wiring; No. Z22004, Rev. D

APPENDIX A-1

FLIGHT TEST PLAN

FZM-12-6552

GENERAL DYNAMICS
Fort Worth Division

8 May 1980

General Test Plan/Procedures
(Flight Test System) for
Advanced Aircraft Fire
Detection System

Item 0002, Sequence 8 of
Attachment #1, DD Form 1423 to
Contract F33615-77-C-2029

I N D E X

1.0 Test Objectives

The test objectives for the Advanced Aircraft Fire Detection System that utilizes ultra violet radiation principles for the detection of aircraft fires is to accomplish the following during flights on an F-111 test aircraft:

a. Demonstrate that no false warnings occur during the flight test program.

b. Demonstrate system reliability when subjected to operational service type environment.

c. By use of an ultra violet radiation generator (Wand), demonstrate that the system has the capability of detecting a fire as it is installed in the test aircraft.

d. Measure safety margins available above random ultra violet radiation that may strike the UV fire detector tubes.

e. Compare the simplified System "B" performance that is installed in one engine nacelle with the performance of System "A" that is more complex in design and is installed in the other engine nacelle.

f. Demonstrate that the detector fire detection sensitivity is not reduced due to contamination collected on the ultra violet (UV) fire detector tubes during aircraft operation.

g. Demonstrate the reliability of the system in a maintenance environment (Example, engine removal and installation).

2.0 System Description

The systems to be flight tested utilize ultra violet (UV) radiation energy present in hydrocarbon fires for their operation. The UV fire detector tube is made of a borosilicate glass envelope containing metal electrodes and a low gas filling. The UV energy from a fire ionizes the gas and causes the electrodes to conduct and allow current flow.

Each system is comprised of UV fire detector units, a computer control unit (CCU), and a crew warning unit (CWU).

Two systems will be installed on an FB-111A test aircraft. System "A" incorporates dual UV fire detector heads, automatic self testing, redundant components, and fire detection verification using the dual detector heads and software programming. These design features result in a high degree of reliability. System "B" is a simplified version of System "A". System "B" will use one UV fire detector head and one half of the components in the CCU of System "A". These two systems will be completely independent from the production installed fire detection system.

System "A" will be installed in the left engine nacelle and System "B" will be installed in the right hand engine nacelle. One CCU for System "A" and one CCU for System "B" will be installed in the electronics bay. A common crew warning unit (CWU) panel will be installed in the crew compartment. This panel will incorporate a fire warning light and a fail indication light for System "A" and a fire warning light and a fail indication light

2.0 continued:

for System "B". Two test switches will be used. One test switch will test the fire warning portion of the system of both System "A" and System "B" simultaneously. The other test switch will be to test the fail indication portion of the system of both System "A" and System "B" simultaneously.

3.0 Maintenance Checkout Unit (GSE)

The GSE is utilized for two Modes of operation. The Data gathering mode will be used after each flight to interrogate the CCU memory to measure safety margins and other events during flight that are useful for evaluating system operation. The Test Mode will be used to check system operation. Self contained battery packs in the System "B" CCU will maintain electrical power on both systems to retain flight data in the memory banks after engine shut down in order for the GSE to obtain stored flight data.

4.0 Installation Description

Installation of System "A" and System "B" is as shown on Figure 1 & 2. The installation of these two systems will require the removal of both engines. Five dual UV fire detectors are installed in the left hand engine nacelle for System "A" and five single UV fire detectors are installed in the right hand engine nacelle for System "B". The location of the detectors are as follows:

4.0 continued:

- Lower engine fire wall, Fuselage Station 593.
- Outboard engine access door forward of Fuselage Station 725 frame.
- Forward surface of inboard Fuselage Station 770 frame.
- Upper aft inboard surface of Fuselage Station 770 frame.
- Upper aft outboard surface of Fuselage Station 770 frame.

A CCU for System "A" and a CCU for System "B" is installed in the electronic equipment bay as shown on Figure 3.

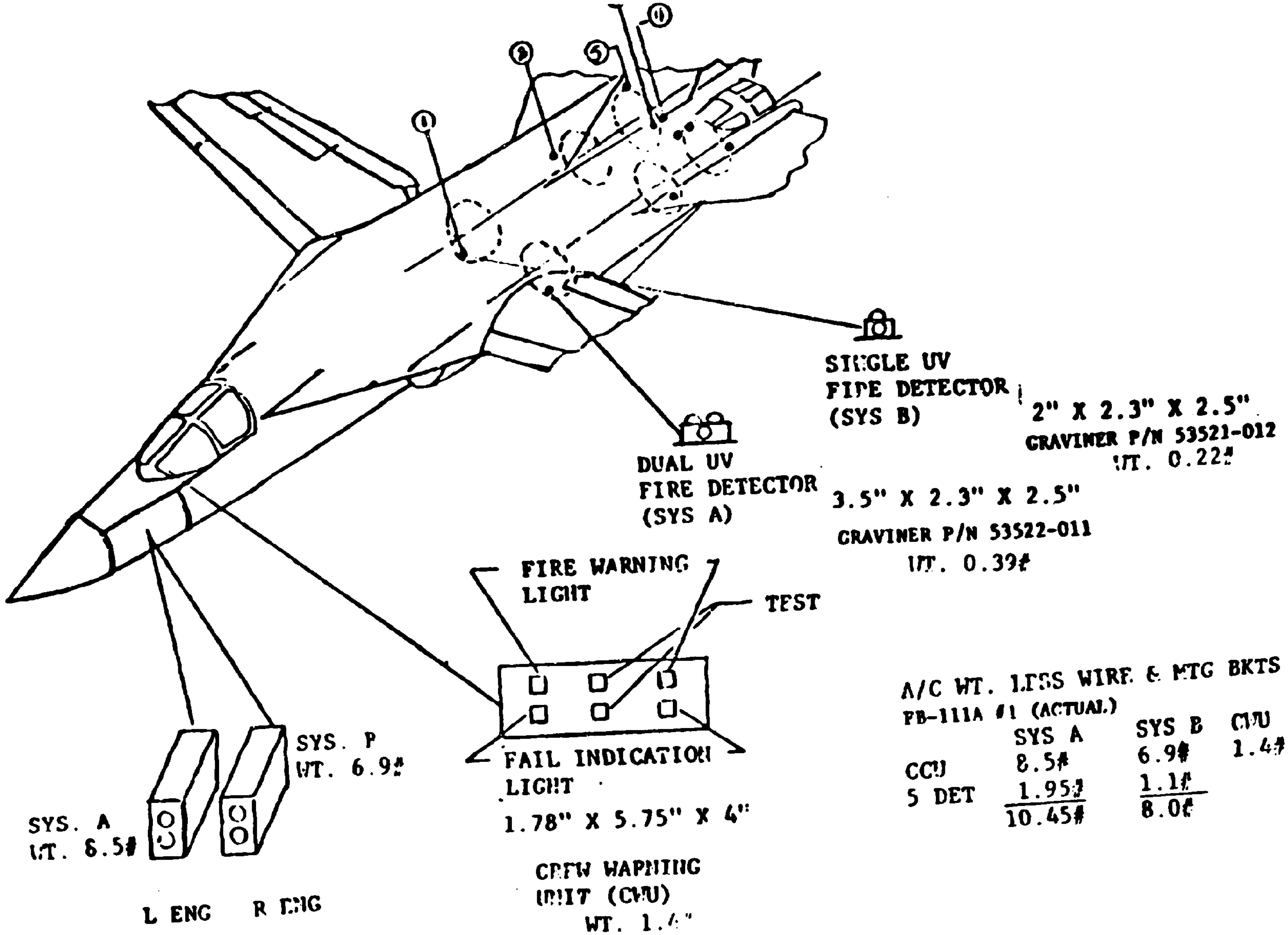
A Crew Warning Unit (CWU) is installed in the crew compartment as shown on Figure 4. High temperature shielded and unshielded wire will be routed from the UV fire detectors of each system through electrical connectors on the engine fire wall. One electrical connector will be added to the left engine fire wall. An existing connector on the right hand fire wall will be utilized for routing of System "B" elctrical wire.

115 Volt 400 hertz power will be required for the operation of each system along with 28 Volt DC for the lights and switches on the CWU.

5.0 Functional Checks

The following is planned for the functional checks: with the engines removed and prior to engine installation, apply power to the systems and check systems utilizing the GSE, a UV wand to simulate a fire, and the CWU test switches in the crew station.

After engines are installed, repeat the above check with the engine access doors open.



ADVANCED AIRCRAFT UV FIRE DETECTION
SYSTEM INSTL ON FB-111A#1 TEST AIRCRAFT
CRAD F33615-77-C-2029

Figure 1

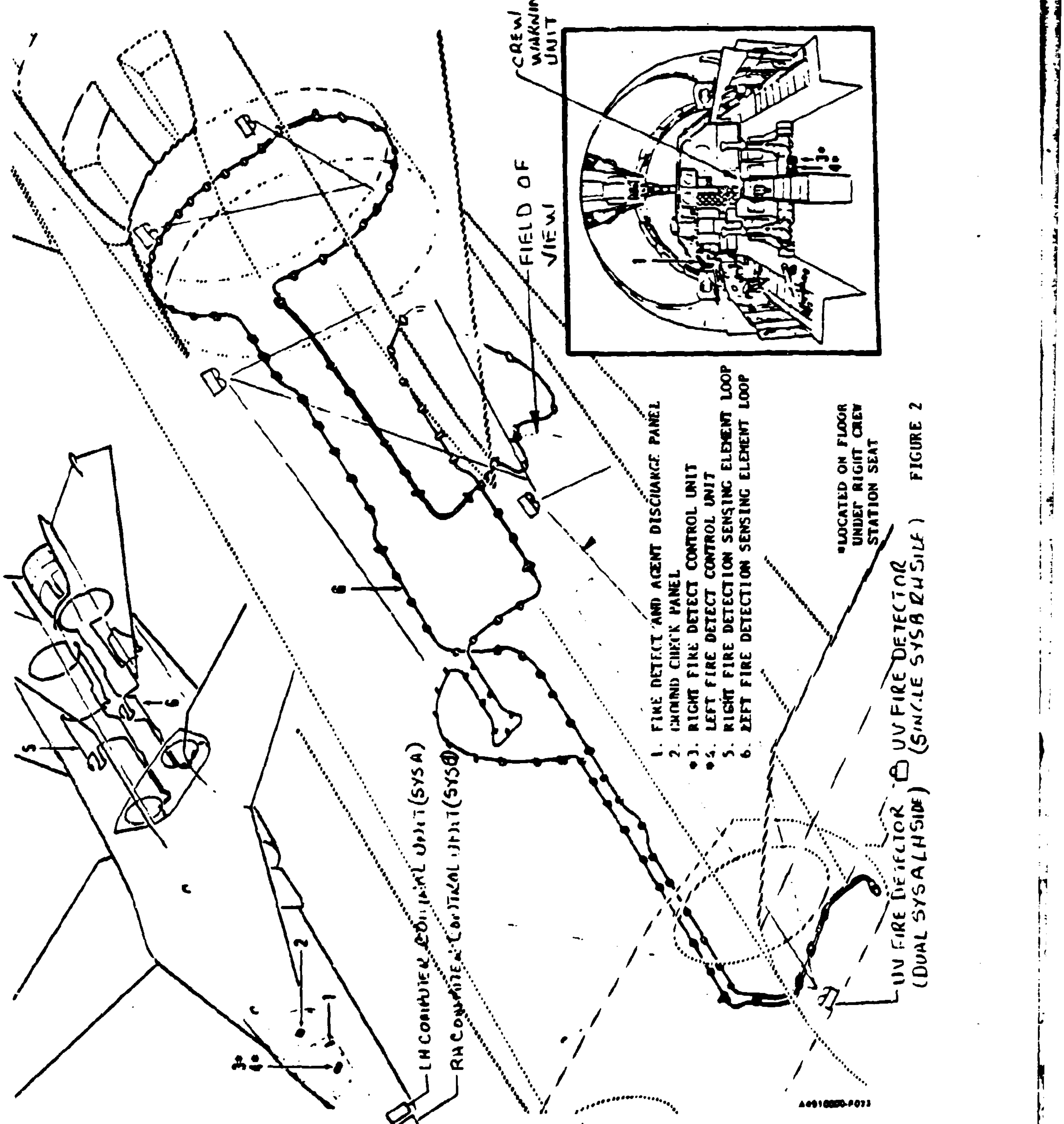
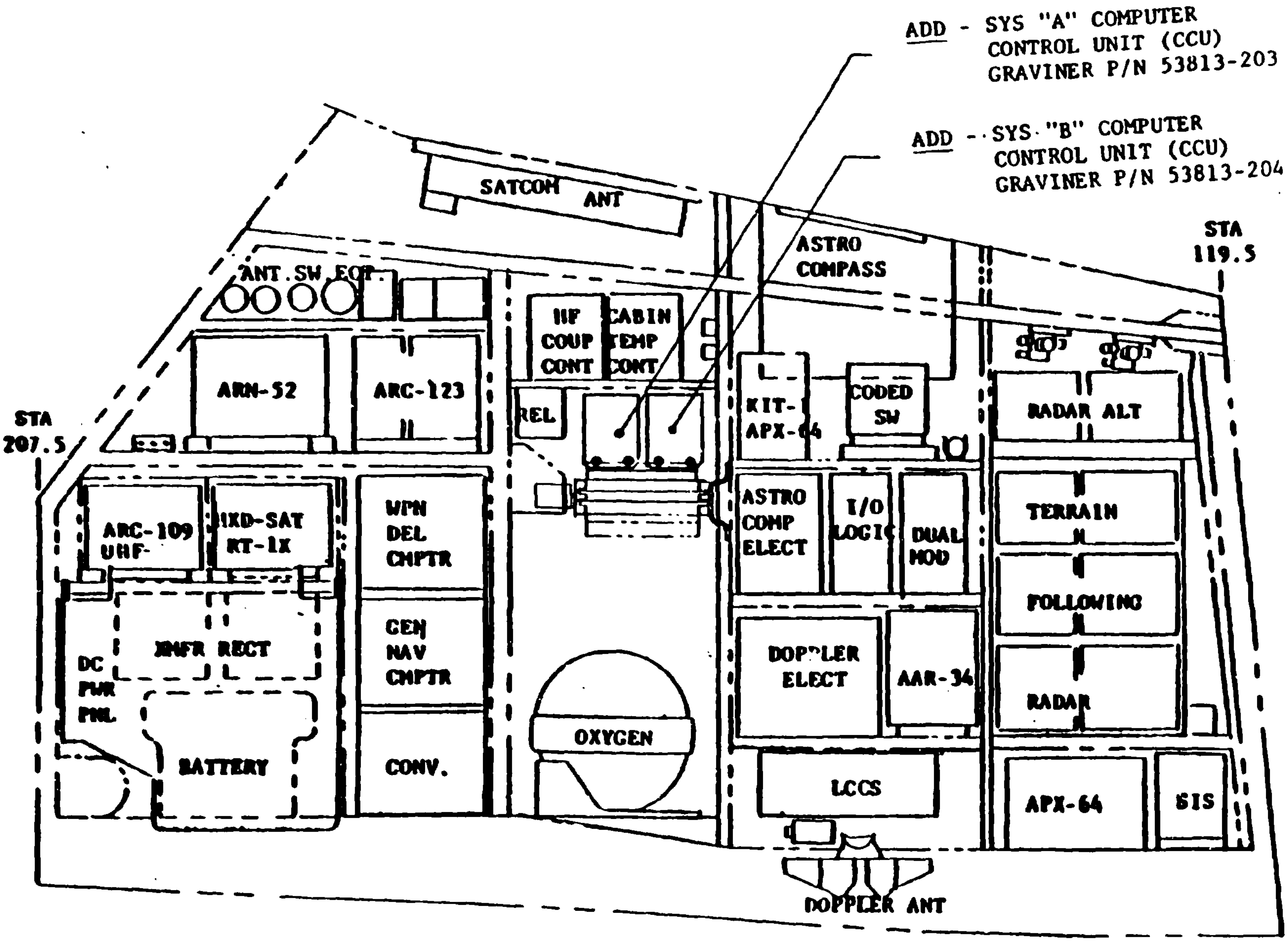


Figure 17-6. Engine Fire Detection System Component Location (Prior to T.O. 1F-111-1151)



VIEW LOOKING INBD RH EQUIP. BAY
FB-111A NO. 1

Figure 3

FB-111 CREW STA ARRANGEMENT (APL 1) 9/22/80

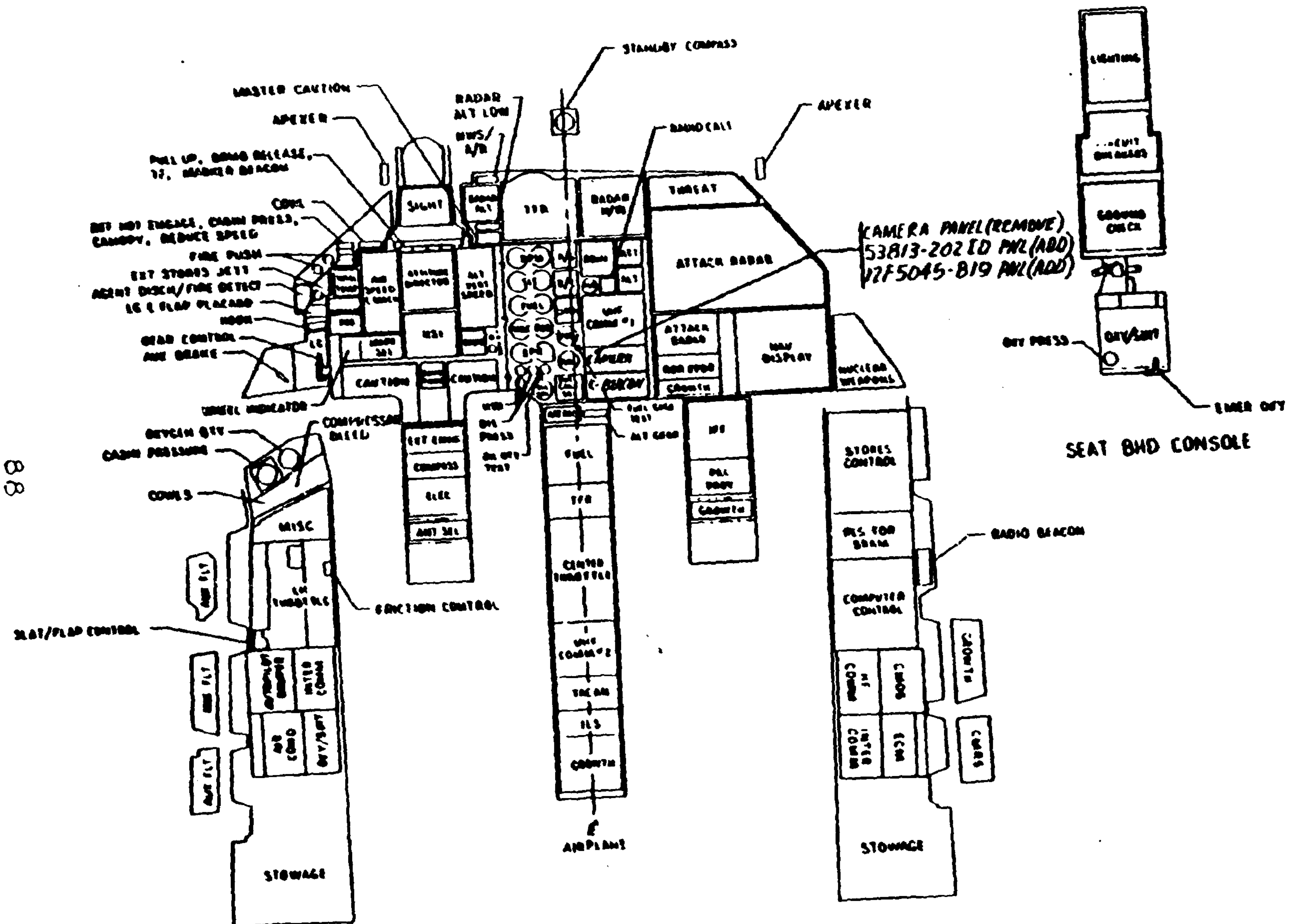


Figure 4 Crew Warning Unit (CCU) Arrangement For Advanced Fire Detection System

6.0 Initial Engine Run Checks

a. Prior to engine start up, and as soon as power is supplied, check System "A" and System "B" by means of the test switches on the CWU. Record the time the test switches are pressed.

NOTE: Electronic log of this timing is also carried in the CCU for readout by the GSE.

b. When checks have been completed, start engines and ground run for 15 minutes. Afterburner operation must be included with a log of the start and stop times of afterburner use.

c. Shut engines down and check systems using the GSE.

d. Restart engines, taxi and locate aircraft in sunlight on parking apron. Note ambient temperatures. Run engines at idle for a period of ten minutes. Rotate aircraft 90°, idle again for ten minutes. Repeat 360° rotation of aircraft has been completed. Note positions and timing in log.

e. Shut down engines and check systems using the GSE.

7.0 Initial Flight Test

a. Perform crew station checks and note time of test switch operation.

b. Fly two circuits of the airfield and land.

c. Recheck system using GSE.

d. Park aircraft in hot sun for five hours, nose north, with ground power on and system energized.

e. Recheck system using GSE.

7.0 Flight Test Procedure

System flight testing shall consist of two parts (1) dedicated sorties and (2) service experience concurrent with other flight testing.

7.1 Dedicated Sorties

The following is the specific flight profiles required in addition to service experience from other flight testing:

7.1.1 Initial Flight

(a) Perform crew station checks of fire warning and fail caution light and note time of test switch operation.

(b) Takeoff and fly two circuits of base and land.

(c) Connect Ground Service Equipment (GSE) and check system and obtain data.

(d) Park aircraft in hot sun for five hours, nose north, with ground power on and system energized.

(e) Recheck system using GSE.

7.1.2 Takeoff and Climb 10-15K feet, maintain level flight at 3 subsonic speeds.

(a) Prior to takeoff perform crew station checks of fire warning and fail caution lights and note time of test switch operation.

(b) After landing connect GSE, check system and obtain data.

7.1.3 Subsonic climb to max altitude and cruise.

(a) Prior to takeoff perform crew station checks of fire warning and fail caution lights and note time of test switch operation.

(b) Dive supersonic for 5 seconds with sun behind aircraft.

(c) After landing connect GSE, check system and obtain data.

7.1.4 Supersonic climb, 5 minute run at high speed and max power.

(a) Prior to takeoff perform crew station checks of fire warning and fail caution light test switches and note time of test switch operation.

(b) After landing connect GSE, check system and obtain data.

7.2 Service experience and data collection concurrent with other flight testing.

(a) Perform crew station checks of fire warning and fail caution light and note time of test switch operation.

(b) After flight connect GSE, check system and obtain data.

7.3 Data Collection

7.3.1 The following data is required from each flight.

(a) Air Speed

(b) Altitude

(c) Mach Number

(d) Outside Air Temperature

(e) Voice

(f) Time

(g) Weather Conditions

(h) Afterburner Operation Time.

(i) Ambient temp at each UV fire detector location.

Data collection via voice recordings and transcribed are acceptable and should be made available in the same time frame as print outs obtained from the GSE. The time at which the fire warning switch is energized is used to relate to any fire indication and/or to data stored in the memory system of the on-board computer control units during flight. Data to be selected to actual flight identification.

7.3.2 The recordings and associated hard copy printout obtained from the GSE should be attached to a copy of the above data collection record and transmitted to the Contractor for evaluation. The above flight test data should be made available for the dedicated flights and other service data experience for a minimum period of three months.

8.0 Engines from left and right hand sides should be removed, detectors inspected, engine replaced, and system checked using the GSE.

9.0 Certification

9.1 Hazard Analysis - FZM-12-14101

9.2 Electromagnetic Compatibility Test Plan - The electromagnetic compatibility testing will be accomplished per Electromagnetic Test Plan FB-111A No. 1 Electromagnetic Interference Safety-of-Flight Acceptance Test Procedure for Advanced Aircraft Fire Detection System, FZE-12-6099.

10.0 Operation and Maintenance Instructions - Operation and Maintenance Instructions are contained in the subcontractor, Graviner, Manual identified as MM055.

11.0 Associated Drawing List

11.1 Aircraft Installation Drawings (New)

Drawing Title	Number
System A Instl - Advanced Aircraft Fire Detection System	12FTP2109
System B Instl - Advanced Aircraft Fire Detection System	12FTP2111
Advanced Aircraft Fire Detection System	12FTP2110
Wiring Diagram - Advanced UV Fire Detect System	12FTD244
Control Unit Instl - Ultra Violet Advanced Fire Detect System	12FTE325
Lower Firewall BHD-UV Advanced Fire Detect, Rework of	12FTE326
Control Unit Instl - Ultra Violet Advanced Fire Detect System	12FTE327

11.2 UV Digital Fire Detection System Equipment

Name	Subcontractor (Graviner) Part Number
Computer Control Unit, System A	53813-203
Computer Control Unit, System B	53813-204
U.V. Detector (Single Head), System B	53521-012
U.V. Detector (Dual Head), System A	53522-011
Crew Warning Unit, Systems A & B	53813-202
Ground Support Equipment (GSE)	51659-062

APPENDIX A-2

FLIGHT TRIALS DATA READOUTS

SYSTEM B
AUTO MODE
SELECTED

START READ CCU TEST

Prior engine run
3/7/80

GRUTIL V. 4
->!M4400
```
33A5A5A5000000000000000000000000
00000000000000000000000D0080BB00
00000E00081000FC24D5FB027E000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000278F0010158F001000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000009123D3
00000000000000000000000000000000
00000000000000000000000000000000
0000000000000000000000000D0F0010
8E001023000100F10000000000000000
00000000FF00FFE06600000FD02500FF
FF000055555555555555555555555555
55555555555555555555555555555555
```

->
GRUTIL V. 4
->!M4400
```
33A5A5A5000000000000000000000000
00000000000000000000000D0080BB00
00000E00081000FC24D5FB027E000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000278F0010158F001000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000009123D3
00000000000000000000000000000000
00000000000000000000000000000000
0000000000000000000000000D0F0010
8E001023000100F10000000000000000
00000000FF00FFE06600000FD02500FF
FF000055555555555555555555555555
55555555555555555555555555555555
```

CCU TEST COMPLETE

START CONTROL UNIT TESTS

GRAVINER DFDS
F-111 CONFIRMED

000000000000000
CONTROL UNIT TESTS COMPLETE

START UV-HEAD TEST

SIDE 1
UV-HEAD 1 2168
UV-HEAD 2 2168
UV-HEAD 3 2016
UV-HEAD 4 2117
UV-HEAD 5 2046

UV-HEAD TEST COMPLETE

START FUNCTIONAL TEST

```
00000000000000000000000000000000
0000000000000000000000000
```
FUNCTIONAL TEST COMPLETE

START DATA ANALYSIS
ALL HEADS OK
FLIGHT DATA FOLLOWS
(TIME IN MINUTES)
RIGHT ENG
FIRE EVENTS= 1
FIRE AT - 11
AREA 3
FIRE OUT AT - 11
AREA 3
(BACKGROUND NOT VALID)
END OF DATA ANALYSIS

END OF ALL TESTS
SYSTEM INTEGRITY
CONFIRMED

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FIG. 1

GD/GRAVINER DFDS AUTO TEST ROUTN

SYSTEM B
AUTO MODE
SELECTED

START READ CCU TEST

3rd engine run

GRUTIL V. 4 5/9/80

```
->!M4400
33A5A5A5000000000000000000000000
0000000000000000000000A900007C00
00000E08081000AE08345A05CC000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000009123D3
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000100E0000000000000000
00000000FF00FFE06600000FD02500FF
FF000055555555555555555555555555
55555555555555555555555555555555
```

```
->
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
0000000000000000000000A900007C00
00000E08081000AE08345A05CC000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000009123D3
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000100E0000000000000000
00000000FF00FFE06600000FD02500FF
FF000055555555555555555555555555
55555555555555555555555555555555
```

->READ CCU TEST COMPLETE

START CONTROL UNIT TESTS

GRAVINER DFDS
F-111 CONFIRMED

0000000000000000
CONTROL UNIT TESTS COMPLETE

START UV-HEAD TEST

SIDE 1
UV-HEAD 1 2163
UV-HEAD 2 2165
UV-HEAD 3 2030
UV-HEAD 4 2117
UV-HEAD 5 0000

UV-HEAD TEST COMPLETE

START FUNCTIONAL TEST

```
00000000000000000000000000000000
00000000000000000000000000
```

FUNCTIONAL TEST COMPLETE

START DATA ANALYSIS
REPLACE HEAD
5
FLIGHT DATA FOLLOWS
(TIME IN MINUTES)
RIGHT ENG

LEVEL	COUNT	TIME	HEAD
1(1)	0		
2	0 -	31	
3	0 -	31	
4	0 -	31	
5	0 -	31	

END OF DATA ANALYSIS

END OF ALL TESTS
SYSTEM INTEGRITY
CONFIRMED

-REMOVE PAPER-

FIG. 2

GD/GRAVINER DFDS AUTO TEST ROUTN

SYSTEM A
MANUAL MODE
SELECT TEST ?

failed head Why

see over

START READ CCU TEST

```
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
00000000000000000000000000002B00
000000000009002D222536005C000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000050AF7
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000002A00B0000000000000000
0000000000000E066000000FD02500E6
E2E7E3E6E2E6E2E6B2AAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

FAILED HEAD 2

```
->
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
00000000000000000000000000002B00
000000000009002D222536005C000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000050AF7
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000002A00B0000000000000000
0000000000000E066000000FD02500E2
E2E7E3E6E2E6E2E6E2AAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

```
->
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
00000000000000000000000000002B00
000000900000002D2125350116000000
00000000000000000000000000000000
00000000001200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000000A059
00000000000000000000000000000000
00000000000000000000000000000000
0000000000000000000C900000000000
000000000000100F00000000C0000000
0000000000000E066000000FD02500E4
E4E1E5E0E4E0E4E0E4E0E4E0E4E0E4E0
E4E0E4E0E4E0E4E0E4E0E4E055555555

->READ CCU TEST COMPLETE
```

MANUAL MODE
SELECT TEST ?

START CONTROL UNIT TESTS

GRAVINER DFDS
F-111 CONFIRMED

0000000000000000
CONTROL UNIT TESTS COMPLETE
MANUAL MODE
SELECT TEST ?

FIG. 3

1St draft
9/1/80

Sys A Side 1

```
!M4400                          33
A5A5A500000000000000000000000000
00000000000000000000000000A30100
00009000000036E292C2807B90000000
00000000000000000000000000000000
000000001300000000000000000000FF
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
0000000000000000000000000000D300
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000100E0000000000000000000
000000000000E06600000FD02500E6E2
E7E3E6E2E6E2E6E2E6E2E6E2E6E2E6E2
E6E2E6E2E6E2E6E2E6E2E6E2E6E255!
```

```
M4400   Sys A side 1            33A
5A5A5000000000000000000000000000
0000000000000000000000000A301000
0000000000036E292D3C08AF00000000
00000000000000000000000000000000
00000FF1300000000000000000000FF0
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000912303000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000100E0000000000000000000
00000000000E06600000FD02500FFFF0
00055555555555555555555555555555
```

```
!M4400   Sys B side 1           33
A5A5A500000000000000000000000000
00000000000000000000720380A50100
000E080010037927F01E05CC00000000
00000000000000000000000000000000
000000FF7300000000000000000000FF
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000004800300
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000100E0000000000000000000
000000FF00FFE06600000FD02500FFFF
00005555555555555555555555555555
```

FIG. 4
100

GD/GRAVINER DFDS AUTO TEST ROUTN

SYSTEM A
AUTO MODE
SELECTED

START READ ~U TEST

GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
[illegible]
000000000000381000E3F09850000000
00000000000000000000000000000000
00000000001200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000003
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000100F00000000000000000
00000000000000E06600000FD02500FF
FF000655555555555555555555555555
55555555555555555555555555555555

->
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
0000000000000000000000000000DE00
00000090000003810A0E3E09B8000000
00000000000000000000000000000000
00000000001200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000D00A59
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000100F00000000000000000
00000000000000E06600000FD02500E4
E4E1E5E0E4E0E4E0E4E0E4E0E4E0E4E0
E4E0E4E0E4E0E4E0E4E0E4E0E4E0E455

->READ CCU TEST COMPLETE

START CONTROL UNIT TESTS

GRAVINER DFDS
F-111 CONFIRMED

0000000000000000
CONTROL UNIT TESTS COMPLETE

START UV-HEAD TEST

SIDE 1
UV-HEAD 1 2151
UV-HEAD 2 2104
UV-HEAD 3 2039
UV-HEAD 4 2113
UV-HEAD 5 0000

SIDE 2
UV-HEAD 1 3350
UV-HEAD 2 2166
UV-HEAD 3 2738
UV-HEAD 4 2169
UV-HEAD 5 0000

UV-HEAD TEST COMPLETE

START FUNCTIONAL TEST

00000000000000000000000000000000
00000000000000000000000000
FUNCTIONAL TEST COMPLETE

START DATA ANALYSIS
REPLACE HEAD
5
FLIGHT DATA FOLLOWS
(TIME IN MINUTES)
LEFT ENG

LEVEL	COUNT	TIME	HEAD
1(1)	0		
1(2)	0		
2	0 -	55	
3	0 -	55	
4	0 -	55	
5	0 -	55	

END OF DATA ANALYSIS

END OF ALL TESTS
SYSTEM INTEGRITY
CONFIRMED

-REMOVE PAPER-

FIG. 5

GD/GRAVINER DFDS AUTO TEST ROUTN

2nd + 3rd flight

-----------11/1/86---

SYSTEM B
AUTO MODE
SELECTED

START READ CCU TEST

GRUTIL V. 4
->!M4400
```
33A5A5A5000000000000000000000000
0000000000000000000000000080DF00
00000E08001103851D466C07B9000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000FDFAF7
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000001000100F00000000000000000
00000000FF00FFE06600000FD0250AAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

->
GRUTIL V. 4
->!M4400
```
33A5A5A5000000000000000000000000
0000000000000000000000000080DF00
00000E08001103851D466C07B9000000
00A00000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000FDFAF7
00000000000000000000000000000000
000000000306000000[illegible]00000000000
00000000000000000000000000000000
00000001000100F00000000000000000
00000000FF00FFE06600000FD0250AAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

->READ CCU TEST COMPLETE

START CONTROL UNIT TESTS

GRAVINER DFDS
F-111 CONFIRMED

0000000000000000
CONTROL UNIT TESTS COMPLETE

START UV-HEAD TEST

SIDE 1
UV-HEAD 1 2169
UV-HEAD 2 2162
UV-HEAD 3 2001
UV-HEAD 4 2097
UV-HEAD 5 0000

UV-HEAD TEST COMPLETE

START FUNCTIONAL TEST

00000000000000000000000000000000
0000000000000000000000000000
FUNCTIONAL TEST COMPLETE

START DATA ANALYSIS
REPLACE HEAD
5
FLIGHT DATA FOLLOWS
(TIME IN MINUTES)
RIGHT ENG

LEVEL	COUNT	TIME	HEAD
1(1)	1		
2	0	- 55	
3	0	- 55	
4	0	- 55	
5	0	- 55	

END OF DATA ANALYSIS

END OF ALL TESTS
SYSTEM INTEGRITY
CONFIRMED

-REMOVE PAPER-

FIG. 5(cont'd)

START CONTROL UNIT TESTS

GD/GRAVINER DFDS AUTO TEST ROUTN
4th Flight Sept 12
1430

SYSTEM A
AUTO MODE
SELECTED

START READ CCU TEST

GRUTIL V. 4
->!M4400

```
33A5A5A5000000000000000000000000
00000000000000000000000000008E00
000000000001028A1013400A1C000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
0000000000000000000000000005A0F7
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000100F00000000000000000
000000000000000E0660000FD02500E6
E2E7E3E6E2E7E3E6E2E6E2E6E2E6E2E6
E2E6E2E6E2E6E2E6E2E6E2E6E2AAAAAA
```

->

GRUTIL V. 4
->!M4400

```
33A5A5A5000000000000000000000000
00000000000000000000000000008E00
000000900000028A0F133F0BD0000000
00000000000000000000000000000000
00000000000120000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000D0A059
0000000000000000000000000000A000
00000000000000000000000000000000
00000000000000000000000000000000
00000001000100F00000000000000000
0000002000000E066000000FD02500E0
E4E1E5E0E4E0E4E0E4E0E4E0E4E0E4E0
E4E0E4E0E4E0E4555555555555555555
```

->READ CCU TEST COMPLETE

GRAVINER DFDS
F-111 CONFIRMED

0000000000000000
CONTROL UNIT TESTS COMPLETE

START UV-HEAD TEST

SIDE 1
UV-HEAD 1 2166
UV-HEAD 2 2119
UV-HEAD 3 2048
UV-HEAD 4 2093
UV-HEAD 5 0000

SIDE 2
UV-HEAD 1 3349
UV-HEAD 2 2162
UV-HEAD 3 2759
UV-HEAD 4 2168
UV-HEAD 5 0000

UV-HEAD TEST COMPLETE

START FUNCTIONAL TEST

```
00000000000000000000000000000000
000000000003000000000000000
```

FUNCTIONAL TEST COMPLETE

START DATA ANALYSIS
REPLACE HEAD
5
FLIGHT DATA FOLLOWS
(TIME IN MINUTES)
LEFT ENG

LEVEL	COUNT	TIME	HEAD
1(1)	0		
1(2)	1		
2	0 -	35	
3	0 -	35	
4	0 -	35	
5	0 -	35	

END OF DATA ANALYSIS

END OF ALL TESTS
SYSTEM INTEGRITY
CONFIRMED

FIG. 6

GD/GRAUINER DFDS AUTO TEST ROUTN

4th FLIGHT 12th SEPT 80

SYSTEM B
AUTO MODE
SELECTED

START READ CCU TEST

```
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
00000000000000000000000000008F00
00000E080811028E1DBAE00375000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000000000F7
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000005000100F0000000000000000
00000000FF00FFE06600000FD02500E2
E6000055555555555555555555555555
55555555555555555555555555555555

->
GRUTIL V. 4
->!M4400
33A5A5A5000000000000000000000000
00000000000000000000000000008F00
00000E080811028E1DBAE00375000000
00000000000000000000000000000000
00000000FF1200000000000000000000
FF000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000000000000000000000000000F7
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
000000005000100F0000000000000000
00000000FF00FFE06600000FD02500E2
E6000055555555555555555555555555
55555555555555555555555555555555

->READ CCU TEST COMPLETE
```

START CONTROL UNIT TESTS

1

GRAUINER DFDS
F-111 CONFIRMED

0000000000000000
CONTROL UNIT TESTS COMPLETE

START UV-HEAD TEST

SIDE 1
UV-HEAD 1 2169
UV-HEAD 2 2166
UV-HEAD 3 2002
UV-HEAD 4 2074
UV-HEAD 5 0000

UV-HEAD TEST COMPLETE

START FUNCTIONAL TEST

00000000000000000000000000000000
000000000000000000000000

FUNCTIONAL TEST COMPLETE

START DATA ANALYSIS
REPLACE HEAD
5
FLIGHT DATA FOLLOWS
(TIME IN MINUTES)
RIGHT ENG

LEVEL	COUNT	TIME	HEAD
1(1)	5		
2	0 -	35	
3	0 -	35	
4	0 -	35	
5	0 -	35	

END OF DATA ANALYSIS

END OF ALL TESTS
SYSTEM INTEGRITY
CONFIRMED

-REMOVE PAPER-

FIG. 6(cont'd)

APPENDIX A-3

FLIGHT TEST, HEAT TEMPERATURE DATA

ENGINEERING FLIGHT TEST REPORT

AIRCRAFT	DATE	FLIGHT NUMBER	AIRCREW
FB-111A	12 Sep 80	3	Kunciw/Stokes

TEST PLAN NUMBER	SERIAL NUMBER	TAKEOFF TIME	DURATION OF FLIGHT
408	67-159	1251 Lcl	1.7 hr

TAKEOFF GROSS WEIGHT	PROJECT	PROJECT NUMBER
80,000 lb	UV Fire Detector	MMET 78-11-1058S

PURPOSE

Evaluate UV Fire Detector System located in engine bays.

CONFIGURATION

CLEAN

TEST AND COMMENTS

Profile (KIAS, MSL, Mach, AB is Afterburner)	Time (hr, min, sec)
Initialize UV	12, 29, 35
Takeoff (AB)	12, 50, 45 - 12, 51, 50
Climb to 26,000 (AB)	12, 57, 04 - 12, 58, 58
290/26,000/.71	13, 44, 25 - 13, 45, 30
30,000/.8 (AB)	13, 50, 45
30,000/1.0 (AB)	13, 51, 45
640/31,000/1.68 (AB)	13, 53, 55
650/40,500/2.0 - 2.15 (AB)	13, 55, 15 - 14, 00, 12
Landing	14, 28, 30

There were no inflight trips of the UV sensors.

Temperature data at the UV locations is shown on the attached plots and printouts. Maximum possible error is ± 9°F.

Bohdan G. Kunciw Capt

AFFTC FORM, JUN 78, DAPM, AIR OPR: MMS

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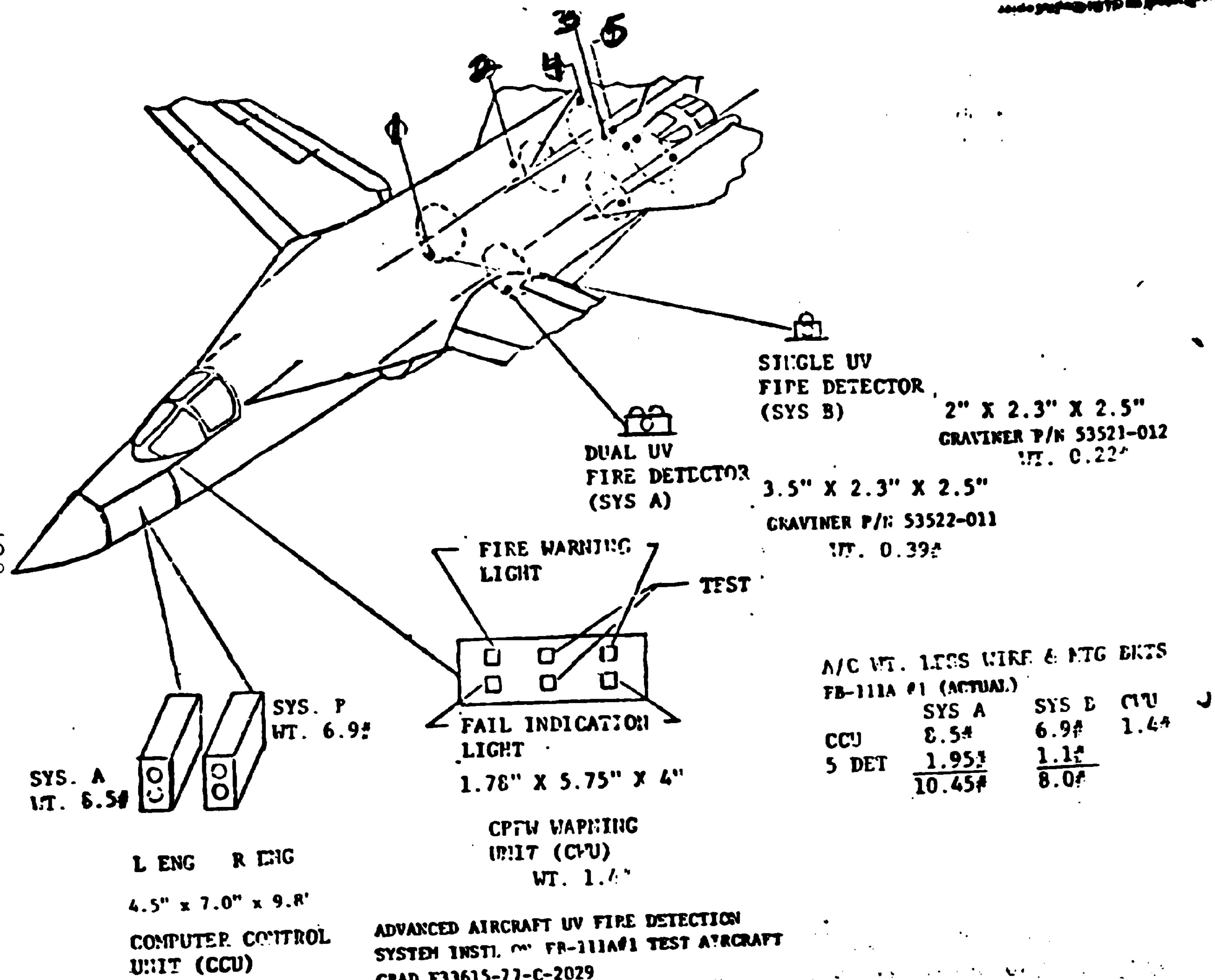
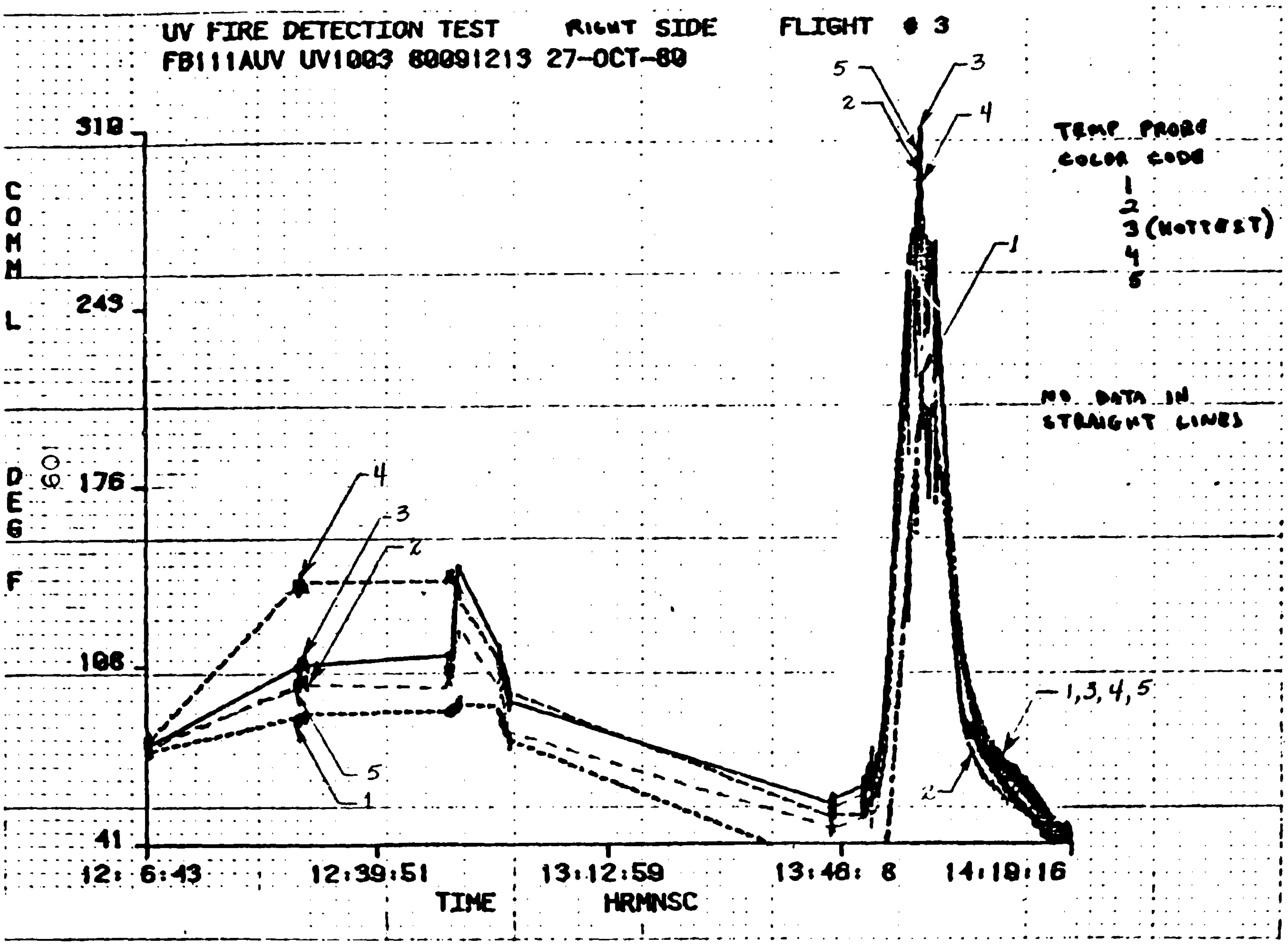
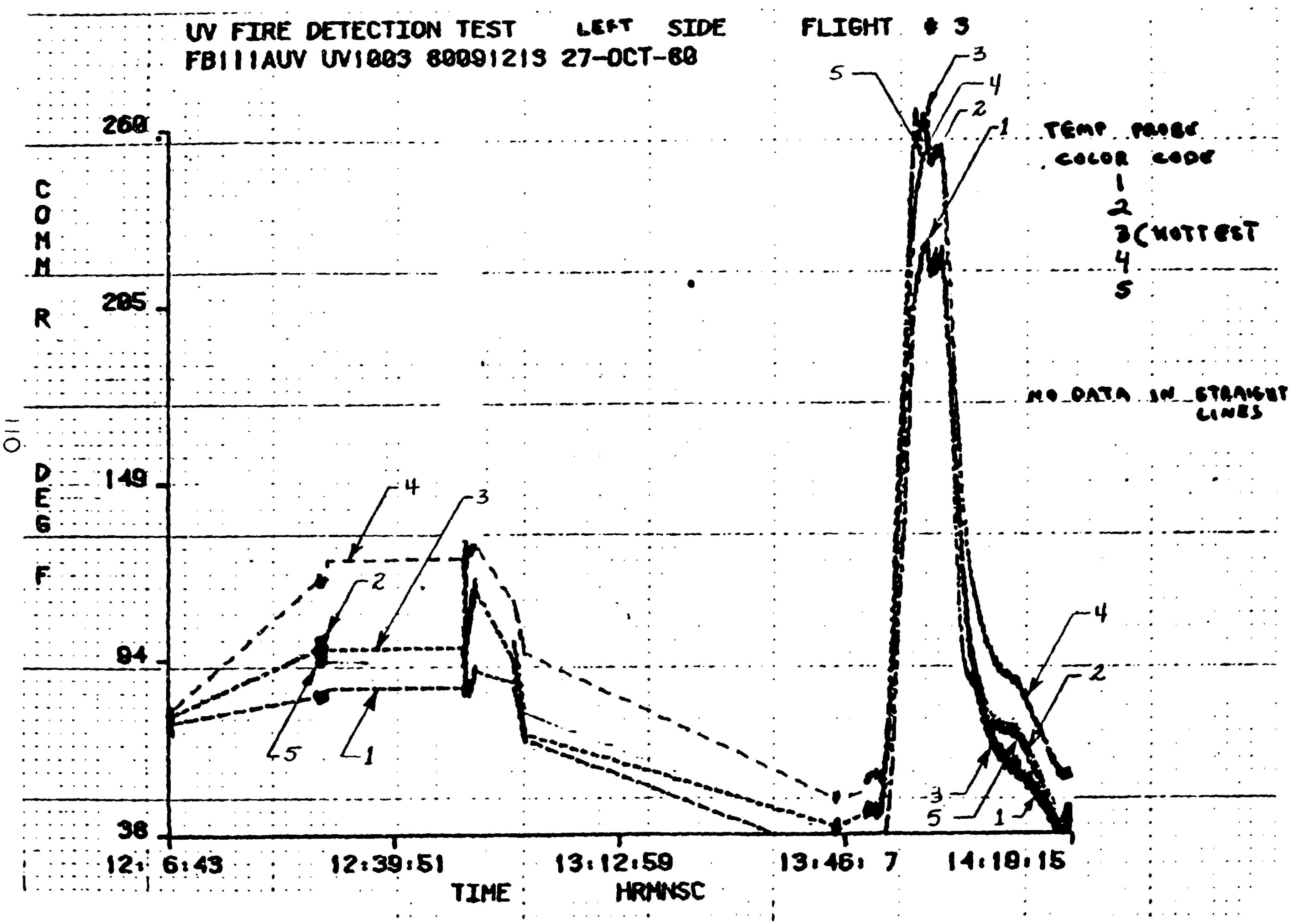


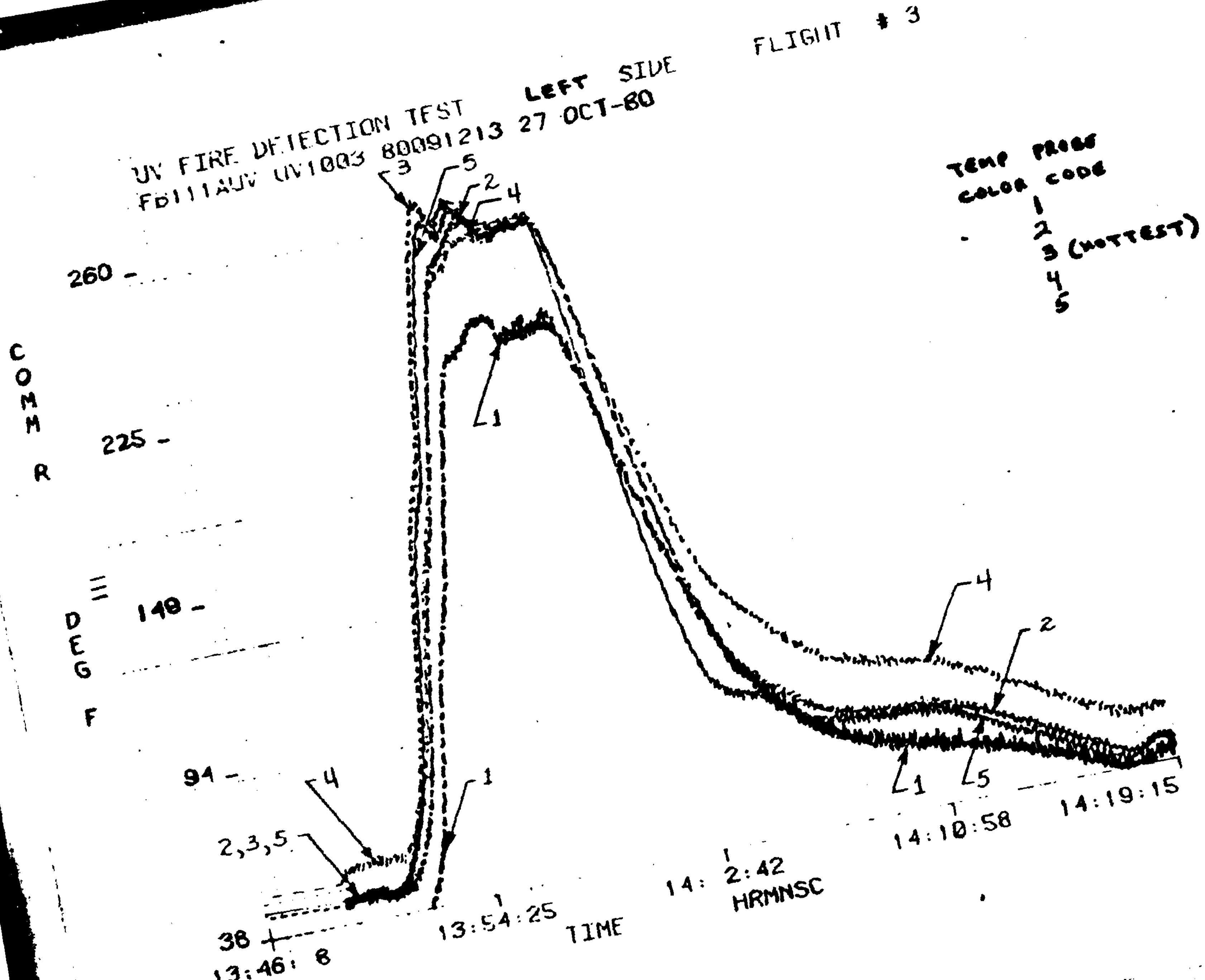
ADVANCED AIRCRAFT UV FIRE DETECTION
SYSTEM INSTL ON FB-111A#1 TEST AIRCRAFT
CRAD F33615-77-C-2029

Figure 3

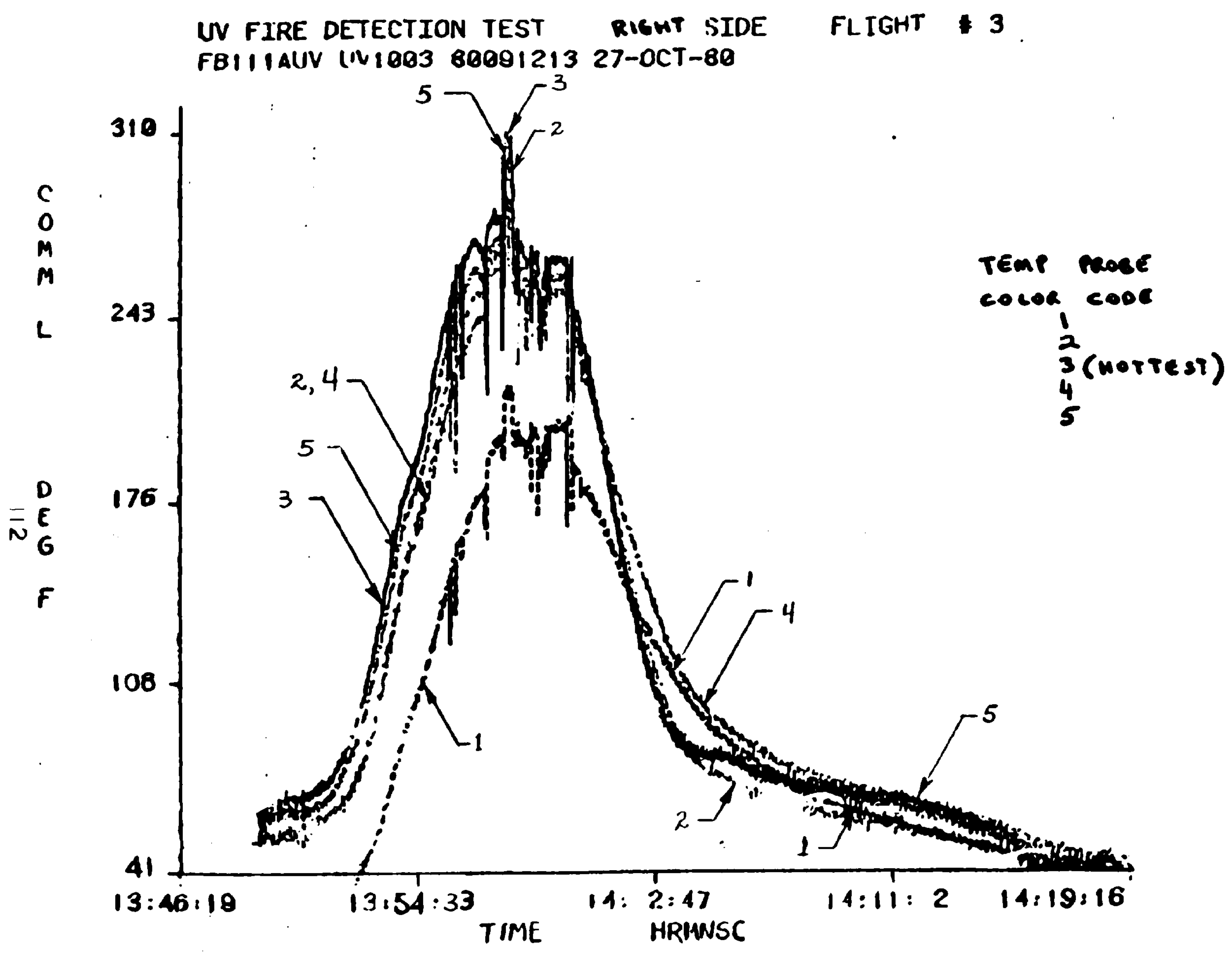


UV FIRE DETECTION TEST
RIGHT SIDE
FLIGHT # 3
FB111AUV UV1003 80091213 27-OCT-80
COMM L DEG F
318
243
176
108
41
12: 6:43
12:39:51
13:12:59
13:48: 8
14:18:16
TIME HRMNSC
TEMP PROBE COLOR CODE
1
2
3 (HOTTEST)
4
5
NO DATA IN STRAIGHT LINES
1,3,4,5
109


UV FIRE DETECTION TEST LEFT SIDE FLIGHT # 3
FB111AUV UV1003 80091213 27-OCT-80
TEMP PROBE COLOR CODE
1
2
3 (HOTTEST
4
5
NO DATA IN STRAIGHT LINES
COMM R DEG F
260
205
149
94
38
12:6:43
12:39:51
13:12:59
13:46:7
14:18:15
TIME HRMNSC
1
2
3
4
5



UV FIRE DETECTION TEST
FB111AUV UV1003 80091213 27 OCT-80
LEFT SIDE
FLIGHT # 3
TEMP PROBE
COLOR CODE
1
2
3 (HOTTEST)
4
5
COMM R
DEG F
260
225
140
94
38
13:46: 8
13:54:25
TIME
14: 2:42
HRMNSC
14:10:58
14:19:15
1
2
3
4
5
2,3,5



UV FIRE DETECTION TEST RIGHT SIDE FLIGHT # 3
FB111AUV UV1003 80091213 27-OCT-80
COMM L
DEG F
310
243
176
108
41
13:46:19
13:54:33
14: 2:47
14:11: 2
14:19:16
TIME HRMNSC
TEMP PROBE
COLOR CODE
1
2
3 (HOTTEST)
4
5
2, 4
5
3
1
2

112

APPENDIX A-4

FAULT WARNING INVESTIGATION

ULTRA VIOLET ADVANCED FIRE DETECTION SYSTEM

Contract No. F33615-77C-2029
(GD P.O. No. 629869 of 18 July 78)

Report of Field Investigation and Associated work at McLellan AFB, Sacramento, 26 May 81 - 02 June 81.

Purpose

To investigate intermittent start-up failure of the U.V. Fire Detection System installed on an F-111 aircraft.

To investigate deficiencies in operate characteristics of GSE Serial 001 and/or to commission GSE Serial 002.

Personnel

R.J. Springer - General Dynamics
D.J.V. Smith, P.H. Sheath - HTL/Graviner

1. Background

During flight trials it had been reported that sometimes initial power up on the aircraft caused System B (right engine) failure lamp to show. On a 2 day visit in March 1981, the problem had not occurred at all and this visit was arranged, with the support of additional equipment, to investigate the problem in greater depth.

In addition, the GSE (S/N 001) had exhibited incorrect print out characteristics. Action was required to investigate this problem and a second GSE (S/N 002) was also delivered to Sacramento.

2. Investigation of UV Detection System

From previous reports, it was apparent that the systems failure was random in nature and that it would be useful to retain data during a failure event for subsequent analysis. A 14 channel FM recorder was provided by HTL together with a digital storage scope for analysis.

The recorder was connected to power supply lines, UV Head and emitter lines of System B via appropriate voltage reduction circuits.

2. Investigation of UV Detection Systems (Continued)

On initial aircraft power switch on, (26 May 81) a System B fail lamp showed and the whole event was recorded.

Analysis showed that UV Head 2 failed to strike during the first auto test period but did respond on subsequent test periods. Heads 1 and 4 were observed to fire late in the first test period and then correctly in subsequent test periods. This combination of late firings was (correctly) interpreted by the CCU as a system failure and the fail light was displayed. Subsequent testing showed that this mode of failure could not be repeated unless the aircraft system was left for several hours between "power ups".

Although flight test personnel at Sacramento had reported failures on system B only, it was established by similar recording and analysis that the dual heads of system A exhibited the same reluctance to start at initial power on. The higher level of redundancy of system A however, masked the effect and systm A (left engine) fail lights did not show.

Initial thoughts on the cause of failure centered around the possibility that head drive voltages might not be established quickly enough and that cable length and capacitive effects might starve the heads of the required firing voltages at initial power-on.

Head 2 on system A was selected for further examination to determine whether sufficient head and emitter voltage was present to cause breakdown and excitation. On two occasions of power-on, voltages appeared to be adequate on both counts. (Precise figures were not available on site because of calibration inaccurracies of the rented equipment but these were determined later from analysis of the FM recorder tapes) Further tests were made to determine whether the problem was in the heads or the CCU head drive circuits and it was shown that the head drive circuits were capable of operation with even increased cable lengths and capacitance. This was also confirmed on duplicate tests conducted simultaneously in the U.K.

It was then possible to isolate the fault as being either the photocells or emitters failing to strike under the application of the 320 V stimulus. During the work in March 81, R69 on the head drive Cards had been removed to delete a possible limiting effect on head drive current. These were replaced in order to provide a Source impedance for monitoring the current drawn at successive emitter firings. It was shown that each head firing did correspond to a step in the emitter voltage characteristic. However, this still did not isolate the cause, it being possible that through current limiting on the head drive circuit, the first head to fire may drop the emitter line voltage.

2. Investigation of UV Detection Systems (Continued)

To further investigate this possibility, a head drive card (taken from GSE 001) was modified so that an external supply could be used to fire emitters only, thus isolating the effects of head drive supply performance. Subsequent runs showed correlation between head firing delay times and steps in the independent emitter drive circuit voltage, thus a clear indication that emitters, not photocells, were the cause of delays.

An additional check on the installation effects was made by adding a 200' cable length to head 2 emitter line on System B. This did not appear to cause any delayed operation of head 2 emitter.

3. Conclusions

3.1 The cause of System B fail light showing during the flight test program is shown to be the reluctance of emitters to fire after an extended off period.

The phenomenon has since been reproduced in laboratory conditions by keeping emitters in light tight photographic bags overnight and demonstrating the same effect. (There is however, a difference in scale in that the slightest amount of radiation stimulus - a pinhole in the bag - appears to be sufficient to eliminate the effect).

3.2 A previously proposed software change to ignore the results from the first few test periods is not now recommended as a solution to the problem. During these investigations emitter firing reluctance has been seen to persist for up to 1½ minutes.

3.3 The continuation of flight testing is proposed, using a flight deck software reset procedure to cancel any fail light. Longer term the effect of reluctant emitters may be solved, for instance, by the addition of a spot of radioactive paint.

3.4 No other faults were found during this very exhaustive investigation and analysis of system performance. There is every reason to believe that the system will now continue to give reliable in flight performance.

APPENDIX A-5

COCKPIT RESET MODIFICATION

ULTRA VIOLET ADVANCED FIRE DETECTION SYSTEM
Contract No. F33615-77C-2029

MODIFICATION PROPOSAL

1. Objective

To provide an easy method of reset for the UVAFDS system from the pilot station without the necessity to access the CCU in the F-111 instrumentation bay. This will enable the cancellation of any test response malfunction at power-up and hence maximise the value of continued test flying.

2. Method

It is proposed to use the existing fire and fault test buttons at the pilot station and arrange that when these buttons are pressed in a pre-determined sequence, a memory reset is effected in the CCU.

Programme control lines exist, running into the CCU via the GSE socket. To cause a new programme to be run, these lines must be set appropriately and actioned by system reset. The CCU then searches for and executes the selected routine.

In the proposed modification the fire and fault test push buttons will be utilized as follows:

The fault test button acts to select the programme required but this will not be run until the fire test button is also pushed, this acting as a reset function. The fire test button acts as a reset command but only if the fault button is also pressed.

With no programme lines selected, the system automatically assumes its normal role of running the fire detection programme.

3. Modifications Required

3.1 CWU

The existing CWU will be replaced by a modified unit prepared by Graviner. The replacement is easily effected on the aircraft but the internal modifications to the CWU are rather too complex to consider on site modification of the existing installed unit.

3.2 Aircraft Wiring

Two additional screened wires are required between the CCU and CWU. (2 wires approximately 8' long each)

These wires are to be fitted to the existing CWU flying socket at one end and to plugs that mate with the GSE socket of the CCU at the other end.

3.3 CCU Logic Cards

An additional diode is to be added to each of the 3 logic cards of the CCU. This involves cutting a circuit track, moving a wire link, fitting the diode and varnish sealing. It is proposed that this work is done by McLelland AFB Staff under the supervision of HTL.

4. Reset Procedure

To effect a reset operation, the following procedure will be used.

a) Press and hold down the FAIL IND TEST button. This will cause both fail lamps to glow.

b) Press and release the FIRE DETECT TEST button. Both fire detect fail lights will extinguish.

c) Wait approximately 3 seconds with FAIL IND TEST button still down.

d) Press and hold down the FIRE DETECT TEST button.

e) Release the FAIL IND TEST button.
L. Engine Fire indication will show in approx. 1.5 seconds.
R. Engine Fire indication will show in approx. 6 seconds.

f) Release FIRE DETECT TEST push button.

Both system A and system B will have been reset by the above procedure and the test buttons resume their normal functions. The fact that normal functions are resumed can be confirmed by the usual pre-flight check.

5. GSE Interaction

The modification described above causes no change in operation of the GSE and requires no modification of the GSE.

A minor procedural change should be noted that before cable 1 from the GSE can be attached to the CCU, the additional flight connected cable to that socket must be removed. This cable may be allowed to hang loose as there are no standing voltages on the pins.

6. Comment

The proposed modification allows a system reset operation to be performed without gaining access to the CCU instrumentation bay. Two minor disadvantages are identified as follows:

6.1 The addition of two new cables could possibly affect the EMC approval. However, the effects are thought to be minimal, especially with the screened cable recommended.

6.2 The modification to the CWU involves separating switch contacts that are currently paralleled. This causes a reduction in reliability of the switch contacts but is considered entirely acceptable.

Dave Smith
23 June 81

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
B1	BATTERY. EVER READY NCC24				
B2	" WITH NSS/A CONTACTS.				
B3	" "				
B4	" "				
B5	" "				
B6	" "				
D1	DIODE	IN645			
D2	"	IN645			
D3	"	IN645			
D4	"	IN645			
R1	RESISTOR	TR6	1K8	5%	
R2	"	TR6	1K8	5%	

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
B	20.5.80							
A	8.4.79							

CERTIFIED | DATE

GRAVINER LTD. ENGLAND.

CHECKED: Jm

TRACED:

DRAWN: JCM

TITLE: BATTERY SUPPLY CARD

SHEET No. 1 OF 1

CIRCUIT COMPONENT LIST FOR: 43761-140 CD

GAF 0293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
C1	CAPACITOR	CK06BX220K	22p	10%	200V
C2	CAPACITOR	CK05BX220K	22p	10%	200V
C3	CAPACITOR	BS5073 N001	15μ	20%	20V
C4	CAPACITOR	CK06BX104K	100n	10%	100V
C5	CAPACITOR	CK06BX104K	100n	10%	100V
C6	CAPACITOR	CK06BX104K	100n	10%	100V
C7	CAPACITOR	CK06BX104K	100n	10%	100V
IC1	COSMAC MICROPROCESSOR CPU	CDP1802CD	-	-	-
IC2	256-WORD × 4 BIT STATIC RAM	CDP1822CD	-	-	-
IC3	256-WORD × 4 BIT STATIC RAM	CDP1822CD	-	-	-
IC4	4 BIT LATCH WITH DECODE	CDP1853CD	-	-	-
IC5	4096 BIT, 512×8, UV EPROM	IM6654MJG	-	-	-
IC6	4096 BIT, 512×8, UV EPROM	IM6654MJG	-	-	-
IC7	4096 BIT, 512×8, UV EPROM	IM6654MJG	-	-	-
IC8	4096 BIT, 512×8, UV EPROM	IM6654MJG	-	-	-
IC9	4096 BIT, 512×8, UV EPROM	IM6654MJG	-	-	-
IC10	4096 BIT, 512×8, UV EPROM	IM6654MJG	-	-	-
IC11	HEX GATE	MC14572UBAL	-	-	-
IC12	DUAL 'D' TYPE FLIP FLOP	CD4013BF	-	-	-
IC13	DUAL 'D' TYPE FLIP FLOP	CD4013BF	-	-	-

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
B	10·3·80							
A	29·3·79	-						

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

CHECKED Jm.

TRACED

DRAWN J.C.M

TITLE: MICROPROCESSOR CARD

SHEET No. 1 OF 2

CIRCUIT COMPONENT LIST FOR: 43761-141-CD.

GAF 4393/78

CIRCUIT REF.	NAME	REF. No	VALUE	TOL. %	RATING
R1	RESISTOR	CR25	10M	10%	0.33 W 250 V.
R2	RESISTOR	TR5	22K	5%	½ W
R3	RESISTOR	TR5	22K	5%	½ W
R4	RESISTOR	TR5	22K	5%	½ W
R5	RESISTOR	TR5	22K	5%	½ W
R6	RESISTOR	TR5	22K	5%	½ W
R7	RESISTOR	TR5	22K	5%	½ W
R8	RESISTOR	TR5	22K	5%	½ W
R9	RESISTOR	TR5	22K	5%	½ W
R10	RESISTOR	TR5	100K	5%	½ W
R11	RESISTOR	TR5	100K	5%	½ W
R12	RESISTOR	TR5	100K	5%	½ W
XL	CRYSTAL. I.T.T. 1D3D(2	MHz 4208)			
D1	DIODE	IN 914			
D2	DIODE	IN 914			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT SHEET
B	10.3.80							
A	29.3.79	–						

CERTIFIED | DATE

GRAVINER LTD. ENGLAND.

CHECKED Jm

TRACED

DRAWN JCM

TITLE: MICROPROCESSOR CARD

SHEET No. 2 OF 2

CIRCUIT COMPONENT LIST FOR: 43761-141.C.D.

GAF 4393/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
C1	CAPACITOR	BS3073 N001	1µ	10%	35V
C2	"	CK05BX102K	1nK	10%	100V
C3	"	CK05BX102K	1nK	10%	100V
C4	"	BS3073 N001	15µ	20%	20V
C5	"	CK06BX104K	100n	10%	100V
C6	"	CK06BX104K	100n	10%	100V
C7	"	CK06BX104K	100n	10%	100V
C8	"	CK06BX104K	100n	10%	100V
C9	"	CK06BX104K	100n	10%	100V
C10/C11	"		1n		100V
D1	DIODE	IN 914			
D2	"	IN 914			
D3	"	IN 914			
D4	"	IN 914			
D5	"	IN 914			
D6	" or	IN 914 IN 4148			
IC1	DUAL BINARY UP-COUNTER	CD4520BF			
IC2	DUAL 'D' TYPE FLIP FLOP	CD4013BF			
IC3	QUAD NOR R/S LATCH	CD4043BF			
IC4	DUAL BINARY UP-COUNTER	CD4520BF			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	12.3.80							
D	10.10.79							
C	4.9.79							
B	10.5.79							
A	3.4.79		F	1.10.87	—			

CERTIFIED | DATE

GRAVINER LTD. ENGLAND.

CHECKED: Jm

TRACED:

DRAWN: J.C.M

TITLE: LOGIC CARD

SHEET No. 1 OF 5

CIRCUIT COMPONENT LIST FOR: 43761-142-C.D

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
IC5	DUAL BINARY UP-COUNTER	CD4520BF			
IC6	QUAD BILATERAL SWITCH	CD4066BF			
IC7	QUAD NOR R/S LATCH	CD4043BF			
IC8	DUAL BINARY UP-COUNTER	CD4520BF			
IC9	DUAL BINARY UP-COUNTER	CD4520BF			
IC10	QUAD BILATERAL SWITCH	CD4066BF			
IC11	QUAD VOLTAGE LEVEL SHIFTER	CD40109BF			
IC12	8 BIT INPUT/OUTPUT PORT	CDP1852CD			
IC13	N BIT 1 OF 8 DECODER	CDP1853CD			
IC14	STROBED HEX INV. BUFFER	CD4502BF			
IC15	8 BIT INPUT/OUTPUT PORT	CDP1852CD			
IC16	DUAL 'D' TYPE FLIP FLOP	CD4013BF			
IC17	8 BIT INPUT/OUTPUT PORT	CDP1852CD			
IC18	QUAD 2 INPUT NAND	CD4011BF			
IC19	QUAD 2 INPUT NAND	CD4011BF			
IC20	HEX BUFFER/CONVERTER	CD4050BF			
IC21	HEX BUFFER/CONVERTER	CD4050BF			
IC22	QUAD 2 INPUT NOR	CD4001BF			
IC23	QUAD 2 INPUT NOR	CD4001BF			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	12.3.80							
D	10.10.79							
C	4.9.79	–						
B	10.5.79	–						
A	3.4.79	–	F	1.10.80	–			

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

CHECKED

TRACED

DRAWN J.C.M.

TITLE: LOGIC CARD

SHEET No. 2 OF 5

CIRCUIT COMPONENT LIST FOR: 43761-142-C.D

REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R1	RESISTOR	TR5	470K	5%	
R2		CR25	1MO	5%	
R3		CR25	10M	10%	
R4		TR4	100K	5%	
R5		TR4	100K	5%	
R6		TR4	100K	5%	
R7		TR4	100K	5%	
R8		TR4	100K	5%	
R9		TR4	100K	5%	
R10		TR4	100K	5%	
R11		TR4	100K	5%	
R12		TR4	100K	5%	
R13		TR4	100K	5%	
R14		TR4	100K	5%	
R15		TR4	100K	5%	
R16		TR4	100K	5%	
R17		TR4	100K	5%	
R18		TR4	100K	5%	
R19		TR4	100K	5%	
R20		TR4	100K	5%	
R21		TR4	100K	5%.	

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
E	12.3.80							
D	10.10.79	–						
C	4.9.79	–						
B	10.5.79	–						
A	3.4.79	–	F	1.10.87	–			

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

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DRAWN J.C.M

TITLE: LOGIC CARD

SHEET No. 3 OF 5

CIRCUIT COMPONENT LIST FOR: 43761-142-C.D.

GA 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R22	RESISTOR	TR4	100K	5%	
R23		TR4	100K	5%	
R24		TR4	100K	5%	
R25		TR4	100K	5%	
R26		TR4	100K	5%	
R27		TR4	2K7	5%	
R28		TR4	2K7	5%	
R29		TR4	10K	5%	
R30		TR4	10K	5%	
R31		TR4	100K	5%	
R32		TR4	22K	5%	
R33		TR4	22K	5%	
R34		TR4	22K	5%	
R35		TR4	22K	5%	
R36		TR4	22K	5%	
R37		TR4	22K	5%	
R38		TR4	22K	5%	
R39		TR4	22K	5%	
R40		TR4	100K	5%	
R41		TR4	100K	5%	
R42		TR4	7K5	5%	

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	2.3.80							
D	10.10.79							
C	4.9.79							
B	10.5.79							
A	3.4.79		F	1.10.81				

CERTIFIED

DATE

GRUNDIG LTD. ENGLAND.

CHECKED

TRACED

DRAWN J.C.M.

TITLE: LOGIC CARD

SHEET No. 4 OF 5

CIRCUIT COMPONENT LIST FOR: 43761-142-C.D.

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R43	RESISTOR	TR4	100K	5%	
R44		TR4	100K	5%	
R45		TR4	100K	5%	
R46		TR4	100K	5%	
R47		TR4	100K	5%	
R48		TR4	100K	5%	
R49		TR4	100K	5%	
R50		TR4	100K	5%	
R51		TR4	22K	5%	

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
F	6.10.87	—						
E	12.3.80							
D	10.10.79							
C	4.9.79	–						

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

CHECKED

TRACED

DRAWN J.C.M.

TITLE: LOGIC CARD

SHEET No. 5 OF 5

CIRCUIT COMPONENT LIST FOR 43[illegible]-142-C.D.

GAF 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
C1	CAPACITOR	ERIE 51012	1µ0	10%	400V
C2		ERIE 51012	47n	10%	630V
C3		BS9073 N001	22µ	10%	35V
C4		BS9073 N001	150µ	10%	16V
C22		ERIE 51012	1µF	10%	400V
C23/C31		ERIE 51012	0.022µF	10%	630V
C5/C8		401EM50AD103M	10n	20%	50V
C9		CK06BX333K	33n	10%	100V
C10		CK06BX333K	33n	10%	100V
C11		CK06BX333K	33n	10%	100V
C12		CK06BX333K	33n	10%	100V
C13/C16		401EM50AD103M	10n	20%	50V
C17		CK06BX333K	33n	10%	100V
C18		CK06BX333K	33n	10%	100V
C19		CK06BX333K	33n	10%	100V
C20		CK06BX333K	33n	10%	100V

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80							
B	7.11.79		G	[illegible]				
A	3.4.79		F	20.6.80				

CERTIFIED | DATE

LTD. ENGLAND.

CHECKED: [illegible]

TRACED

DRAWN: J.C.M

TITLE: DRIVE / SUPPLY CARD

SHEET No. 1 OF 9

CIRCUIT COMPONENT LIST FOR: 43761-143-C.D.

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
D1	DIODE	IN 4007			
D2		IN 4007			
D3		IN 4007			
D4		IN 4007			
D5		IN 645			
D6		IN 645			
D7		IN 645			
D8		IN 645			
D9	- ZENER	BZY 88 C5V1			
D10		IN 645			
D12	- ZENER	BZX 61 C100			
D13		IN 645			
D14		IN 645			
D15		IN 645			
D16		IN 645			
D17	- ZENER	BZY 88 C6V2			
D18		IN 645			
D19		IN 645			
D20		IN 645			
D21		IN 645			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	16·6·80							
D	26·3·80							
C	31·1·80							
B	7·11·79		G	[illegible]				
A	3·4·79		F	20·6·80				

CERTIFIED | DATE

GRAVINER LTD. ENGLAND

CHECKED: [illegible]

TRACED:

DRAWN: JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 2 OF 9

CIRCUIT COMPONENT LIST FOR: 43761-143-C.D.

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
D22	DIODE	IN645			
D23		IN645			
D24		IN645			
D25		IN914			
D26		IN914			
D27		IN914			
D28		IN914			
D29		IN645			
D30		IN645			
D31		IN645			
D32		IN645			
D33		IN914			
D34		IN914			
D35		IN914			
D36		IN914			
D37		IN645			
[illegible]/D45		IN645			
D47/D54		IN4007			
D55/62		IN914			
D46		IN4007			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	13.6.80							
D	26.3.80							
C	31.1.80							
B	7.11.79		G	[illegible]				
A	4.3.79		F	[illegible]	—			

CERTIFIED	DATE
LTD. ENGLAND.	

CHECKED [illegible]

TRACED

DRAWN JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 3 OF 9

CIRCUIT COMPONENT LIST FOR: 43761-143-C.D

134

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R1	RESISTOR	TRS	330K	5%	
R2		TRS	100K	2%	
R3		TRS	20K	2%	
R4		TRS	1K5	2%	
R5		TRS	1M0	5%	
R6		TRS	120K	5%	
R7		TRS	3K3	5%	
R8		TRS	180K	2%	
R9		TRS	~~300K~~	2%	
R11		TRS	S.O.T.	2%	
R12		TRS	200K	2%	
R13		TRS	22K	5%	
R14		TRS	200K	2%	
R15		TRS	22K	5%	
R16		TRS	200K	2%	
R17		TRS	22K	5%	
R18		TRS	200K	2%	
R19		TRS	22K	5%	
R20		MV1A	·10K	5%	2.5W
R21		MV1A	10K	5%	2.5W

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80		H	1.6.8[illegible]				
B	7.11.79		G	~~[illegible]~~				
A	3.4.79		F	10.6.80				

CERTIFIED | DATE

GRAVINER LTD. ENGLAND

CHECKED: Jm

TRACED

DRAWN: JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 4 OF 5

CIRCUIT COMPONENT LIST FOR: 43761-143-C.D.

GAF 4393/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R22	RESISTOR	MVIA	10K	5%	2.5W
R23		MVIA	10K	5%	2.5W
R24		TRS	300K	5%	
R25		TRS	10K	5%	
R26		TRS	300K	5%	
R27		TRS	10K	5%	
R28		TRS	300K	5%	
R29		TRS	10K	5%	
R30		TRS	300K	5%	
R31		TRS	10K	5%	
R32		TRS	4K7	5%	
R33		TRS	4K7	5%	
R34		TRS	4K7	5%	
R35		TRS	4K7	5%	
R36		TRS	200K	2%	
R37		TRS	22K	5%	
R38		TRS	200K	2%	
R39		TRS	22K	5%	
R40		TRS	200K	2%	
R41		TRS	22K	5%	
R42		TRS	200K	2%	

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80		H	1.6.81				
B	7.11.79		G	~~[illegible]~~				
A	3.4.79		F	26.6.80				

CERTIFIED	DATE
GRAVINER LTD. ENGLAND	

CHECKED: [illegible]

TRACED

DRAWN: JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 5 of 9

CIRCUIT COMPONENT LIST FOR: 43761-143-C.D.

GAF 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R43	RESISTOR	TRS	22K	5%	
R44		MVIA	10K	5%	2.5W
R45		MVIA	10K	5%	2.5W
R46		MVIA	10K	5%	2.5W
R47		MVIA	10K	5%	2.5W
R48		TRS	300K	5%	
R49		TRS	10K	5%	
R50		TRS	300K	5%	
R51		TRS	10K	5%	
R52		TRS	300K	5%	
R53		TRS	10K	5%	
R54		TRS	300K	5%	
R55		TRS	10K	5%	
R56		TRS	4K7	5%	
R57		TRS	4K7	5%	
R58		TRS	4K7	5%	
R59		TRS	4K7	5%	
R60		TRS	30K	5%	
R61		TRS	1M0	5%	
R62		TR6	200K	2%	
R63		MVIA	10K	5%	2.5W

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80		H	1.6.81				
B	7.11.79		G	[illegible]				
A	3.4.79		F	12.6.80				

CERTIFIED | DATE

GRAVINER LTD. ENGLAND

CHECKED

TRACED

DRAWN JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 6 OF 9

CIRCUIT COMPONENT LIST FOR 43761-143-C.D.

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R64	RESISTOR	TRS	390K	5%	
R65		TRS	100K	5%	
R66		TRS	30K	5%	
R67		TR6	91K	5%	
R68		TRS	1K0	5%	
R69		TRS	51K	5%	
R70		TRS	10K	5%	
R71		TRS	S.O.T.	2%	
R72		TRS	2K7	5%	
R73		TRS	2K7	5%	
R74		TRS	2K7	5%	
R75		TRS	2K7	5%	
R76		TRS	2K7	5%	
R77		TRS	2K7	5%	
R78		TRS	2K7	5%	
R79		TRS	2K7	5%	
R80/83		TR4	200R	2%	
R88/91		TR4	200R	2%	
R92		TRS	1M0R	2%	

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80		H	1.6.V				
B	7.11.79		G	~~[illegible]~~				
A	3.4.79		F	20.6.80				

CERTIFIED

DATE

GRAVINER LTD. ENGLAND

CHECKED Jm

TRACED

DRAWN JCM

TITLE: DRIVE SUPPLY CARD

SHEET No. 7 OF 9

CIRCUIT COMPONENT LIST FOR: 43761-143-C.D.

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
TR1	TRANSISTOR	MJ 4647			
TR2	(ON EXTERNAL HEATSINK)	BUX67C			
TR3		BUX 67C			
TR4		BCY 70			
TR5		2N 3441			
TR6		2N 3439			
TR7		2N 3439			
TR8		2N 3439			
TR9		2N 3439			
TR10		2N 3439			
TR11		2N 3439			
TR12		2N 3439			
TR13		2N 3439			
TR14		MJ 4647			
TR15		MJ 4647			
TR16		MJ 4647			
TR17		MJ 4647			
TR18		2N 3439			
TR19		2N 3439			
TR20		2N 3439			
TR21		2N 3439			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80		H	1.6.81				
B	7.11.79		G	~~[illegible]~~				
A	3.4.79		F	20.6.80				

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

CHECKED JM

TRACED

DRAWN JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 8 OF 9

CIRCUIT COMPONENT LIST FOR. 43761-143-C D.

GAF 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
TR22	TRANSISTOR	2N3439			
TR23		2N3439			
TR24		2N3439			
TR25		2N3439			
TR26		MJ 4647			
TR27		MJ 4647			
TR28		MJ 4647			
TR29		MJ 4647			
TR30		BC107			
TR31		2N3439			
TR32		2N3439			
TR33		2N3439			
TR34		2N3439			
TR35		BC107			

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
E	19.6.80							
D	26.3.80							
C	31.1.80		H	1.6.87				
B	7.11.79		G	~~[illegible]~~				
A	3.4.79		F	20.6.80				

CERTIFIED

DATE

GRAVINER LTD. ENGLAND

CHECKED

TRACED

DRAWN JCM

TITLE: DRIVE / SUPPLY CARD

SHEET No. 9 OF 9

CIRCUIT COMPONENT LIST FOR 43761-143-C.D

REF.	NAME	REF. No.	VALUE	TOL.	RATING
C1	CAPACITOR	BS9073 N001	100µ	10%	20V
C2	"	BS9073 N001	100µ	10%	20V
C3	"	CK06 BX104K	100n	10%	100V
C4	"	BS9073 N001	18µ	10%	50V
C5	"	CK06 BX104K	100n	10%	100V
C6	"	"	"	"	"
C7	"	"	"	"	"
C8	"	"	"	"	"
C9	"	"	"	"	"
C10	"	"	"	"	"
C11	"	"	"	"	"
C12	"	"	"	"	"
C13	"	"	"	"	"
C14	"	TAA 6.8 M63C	6µ8	20%	63V
C15	"	"	"	"	"

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
H	1.8.80							
G	27.6.80							
F	27.5.80							
E	27.3.80							
D	18.2.80	REDRAWN						

CERTIFIED

DATE

GRAVINER LTD. ENGLAND

CHECKED

TRACED

DRAWN DSR

TITLE. COMMON OUTPUT LOGIC CARD

SHEET No. 1 OF 6

CIRCUIT COMPONENT LIST FOR. 43761-144-CD

CAF 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL.	RATING
D1	DIODE	IN645			
D2	"	IN645			
D3	"	IN914			
D4	"	IN914			
D5	"	IN645			
D6	"	IN645			
D7	" ZENER	BZY88 C7V5			
D8	" ZENER	IN5646A			
D9	"	IN645			
D10	"	IN645			
D11	"	IN4007			
D12	"	IN645			
D13	"	IN645			
D14	"	IN645			
D15	"	IN645			
D16	" ZENER	BZY88 C7V5			
D17	" ZENER	BZY88 C7V5			
D18	DIODE	IN645			
D19	"	IN645			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
H	1.8.80							
G	27.6.80							
F	27.5.80							
E	27.3.80							
D	18.2.80	REDRAWN						

CERTIFIED

DATE

GRAVINER LTD. ENGLAND

CHECKED

TRACED

DRAWN D.J.R.

TITLE: COMMON OUTPUT LOGIC CARD

SHEET No. 2 OF 6

CIRCUIT COMPONENT LIST FOR 43761-144-CD

GAF 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL.	RATING
R1	RESISTOR	TR5	2K7	5%	½W
R2	"	TR5	2K7	5%	½W
R3	"	TR5	22K	5%	½W
R4	"	TR5	22K	5%	½W
R5	"	C5	100K	1%	
R6	"	C5	36K	1%	
R7	"	TR5	100K	5%	½W
R8	"	TR5	100K	5%	½W
R9	"	C5	100K	1%	
R10	"	C5	36K	1%	
R11	"	TR5	100K	5%	½W
R12	"	TR5	100K	5%	½W
R13	"	TR5	100K	5%	½W
R14	"	TR5	100K	5%	½W
R15	"	TR5	100K	5%	½W
R16	"	TR5	100K	5%	½W
R17	"	TR5	100K	5%	½W
R18	"	TR5	100K	5%	½W
R19	"	TR5	22K	5%	½W
R20	"	TR5	22K	5%	½W
R21	"	TR5	10K	5%	½W

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
H	10.80							
G	27.6.80							
F	27.5.80							
E	27.3.80							
D	18.7.80	REDRAWN						

CERTIFIED

DATE

GRAVINER LTD ENGLAND.

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TRACED

DRAWN DJR

TITLE: COMMON OUTPUT LOGIC CARD

SHEET No. 3 OF 6

CIRCUIT COMPONENT LIST FOR 43761-144-CD

GAF 4191/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL.	RATING
R22	RESISTOR	TR5	10K	5%	½W
R23	"	TR5	22K	2%	
R24	"	TR5	3K9	2%	
R25	"	TR5	10K	5%	½W
R26	"	TR5	10K	5%	½W
R27	"	TR5	47K	5%	½W
R28	"	TR5	1K0	5%	½W
R29	"	TR5	10K	5%	½W
R30	"	TR5	1K0	5%	½W
R31	"	TR5	10K	5%	½W
R32	"	TR5	1K0	5%	½W
R33	"	TR5	2K2	5%	½W
R34	"	TR5	2K7	5%	½W
R35	"	TR5	2K7	5%	½W
R36	" FUSIBLE	RESISTA Goold SKS R	15R	5%	-
R37	"	TR5	2K7	5%	½W
R39	"	TR5	2K2	5%	½W
R41	"	TR5	2K2	5%	½W
R42 R43	"	TR5	2k4	5%	½W

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
H	~~10-80~~							
G	2.6.88							
F	5.80							
E	27.3.80							
D	18.2.80	REDRAWN						

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

CHECKED

TRACED

DRAWN DJR

TITLE. COMMON OUTPUT LOGIC CARD 144

SHEET No. 4 OF 6

CIRCUIT COMPONENT LIST FOR 43761-144-CD

GAF 4293/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
IC1	QUAD 2 INPUT NAND GATE	CD4011BF			
IC2	QUAD 2 INPUT NAND GATE	CD4011BF			
IC3	OPERATIONAL AMPLIFIER	LM139D			
IC4	QUAD 2 INPUT NAND GATE	CD4011BF			
RLA	RELAY	27486-803			
RLB	RELAY	27486-803			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
H	[illegible]							
G	27.6.80							
F	[illegible]							
E	27.3.80							
D	18.2.80	REDRAWN						

CERTIFIED

DATE

GRAVINER LTD. ENGLAND.

CHECKED

TRACED

DRAWN DJR

TITLE: COMMON OUTPUT LOGIC CARD

SHEET No. 5 OF 6

CIRCUIT COMPONENT LIST FOR 43761-144-CD

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL.	RATING
TR1	TRANSISTOR	BC107			
TR2	"	BC 107			
TR3	"	BCY 70			
TR4	"	2N 3053			
TR5	"	2N 3053			
TR6	"	2N 3053			
TR7	"	BCY 70			
TR8	"	BC 107			
TR9	"	BC 107			

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
H	1·8·80							
G	17·6·80							
F	27·5·80							
E	13·3·80							
D	18·2·80	REDRAWN						

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DATE

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DRAWN DJR

TITLE COMMON OUTPUT LOGIC CARD

146

SHEET No. 6 OF 6

CIRCUIT COMPONENT LIST FOR 43761-144-CD

CAF 4393/78

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
	CAPACITORS				
C2	"	ES307B N0W	100μ	10%	20V
C3	"	CK06 BX104K	100n	10%	100V
C4	"	ES307B N001	18μ	10%	50V
C5	"	CK06 BX104K	100n	10%	100V
		"	"	"	"
C7	"				
C8	"	"	"	"	"
C9	"	"	"	"	"
C10	"	"	"	"	"
C12	"	"	"	"	"
C13	"	"	"	"	"
C14	"	TAA 6B M63C	6μ8	20%	63V
C15	"	"	"	"	"

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
F	1-8-80							
E	27.6.80							
D	10.5.80							
C	27.3.80							
B	18.7.80	REDRAWN						

CERTIFIED

DATE

[redacted] LTD. ENGLAND.

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DRAWN DSR

TITLE: SYSTEM 2 COMMON OUTPUT LOGIC CARD

SHEET No. 1 OF 6

CIRCUIT COMPONENT LIST FOR: 43761-146-CD

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
D1	DIODE	IN645			
D3	"	IN914			
D5	"	IN645			
D7	" ZENER	BZY88 C7V5			
D8	" ZENER	IN5646A			
D9	"	IN645			
D10	"	IN645			
D11	"	IN4007			
D12	"	IN645			
D13	"	IN645			
D14	"	IN645			
D15	"	IN645			
D16	" ZENER	BZY88 C7V5			
D17	" ZENER	BZY88 C7V5			
D18	DIODE	IN645			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
F	1-8-80							
E	17.6.80							
D	27-5-80							
C	27-3-80							
B	18-2-80	REDRAWN						

CERTIFIED

DATE

[illegible] LTD. ENGLAND

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TRACED

DRAWN D/R

TITLE: SYSTEM 8 COMMON OUTPUT LOGIC CARD

SHEET No. 2 OF 6

CIRCUIT COMPONENT LIST FOR 43761-146

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R1	RESISTOR	TR5	2K7	5%	½W
R3	"	TR5	22K	5%	½W
R5	"	C5	100K	1%	
R6	"	C5	36K	1%	
R7	"	TR5	100K	5%	½W
	"				
R11	"	TR5	100K	5%	½W
R13	"	TR5	100K	5%	½W
R15	"	TR5	100K	5%	½W
R16	"	TR5	100K	5%	½W
R17	"	TR5	100K	5%	½W
R18	"	TR5	100K	5%	½W
R19	"	TR5	22K	5%	½W
R20	"	TR5	22K	5%	½W
R21	"	TR5	10K	5%	½W

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
F	1-8-80							
E	10.6.80							
D	23.5.80							
C	27.3.80							
B	8.2.80	REDRAWN						

CERTIFIED | DATE

GRAVINER LTD. ENGLAND.

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TRACED

DRAWN DJR

TITLE: SYSTEM 8 COMMON OUTPUT LOGIC CARD

SHEET No. 3 OF 6

CIRCUIT COMPONENT LIST FOR: 43761-146-CD

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R22	RESISTOR	TR5	10K	5%	½W
R23	"	TR5	22K	2%	
R24	"	TR5	3K9	2%	
R25	"	TR5	10K	5%	½W
R26	"	TR5	10K	5%	½W
R27	"	TR5	47K	5%	½W
R28	"	TR5	1K0	5%	½W
R29	"	TR5	10K	5%	½W
R30	"	TR5	1K0	5%	½W
R31	"	TR5	10K	5%	½W
R32	"	TR5	1K0	5%	½W
R33	"	TR5	2K2	5%	½W
R34	"	TR5	2K7	5%	½W
R35	"	TR5	2K7	5%	½W
R36	" FUSIBLE	RESISTA GMBH SKS2	15R	5%	–
R37	"	TR5	2K7	5%	½W
R39	"	TR5	2K2	5%	½W
R41	"	TR5	2K2	5%	½W
R42 R43	"	TR5	2K4	5%	½W

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
F	1-8-80							
E	17-6-80							
D	22-5-80							
C	27-3-80							
B	18-2-80	REDRAWN						

CERTIFIED

DATE

[illegible] LTD. ENGLAND.

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TRACED

DRAWN DJR

TITLE: SYSTEM 3 COMMON OUTPUT LOGIC CARD

SHEET No. 4 OF 6

CIRCUIT COMPONENT LIST FOR: 43761-146-CD

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
IC1	QUAD 2 INPUT NAND GATE	CD4011BF			
IC3	OPERATIONAL AMPLIFIER	LM139D			
IC4	QUAD 2 INPUT NAND GATE	CD4011BF			
RLA	RELAY	27486-803			
RLB	RELAY	27486-803			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
F	[illegible]							
E	27.6.80							
D	[illegible]							
C	27.3.80							
B	18.2.80	REDRAWN						

CERTIFIED | DATE

QUANTEL LTD. ENGLAND.

SYSTEM B

CHECKED

TRACED

DRAWN DJR

TITLE: COMMON OUTPUT LOGIC CARD

SHEET No. 5 OF 6

CIRCUIT COMPONENT LIST FOR: 43761-146-CD

CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
TR1	TRANSISTOR	BC107			
TR2	"	BC 107			
TR3	"	BCY 70			
TR4	"	2N 3053			
TR5	"	2N 3053			
TR6	"	2N 3053			
TR7	"	BCY 70			
TR8	"	BC 107			
TR9	"	BC 107			

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT SHEET
F	1-[illegible]							
E	27.6.80	-						
D	27.5.80							
C	27.3.80							
B	18.2.80	REDRAWN						

CERTIFIED

DATE

LTD. ENGLAND.

SYSTEM B

CHECKED

TRACED

DRAWN

TITLE: COMMON OUTPUT LOGIC CARD

SHEET No. 6 OF 6

CIRCUIT COMPONENT LIST FOR: 43761-146-CD

REF.	NAME			TOL.	RATING
C1	CAPACITOR	BS9073 N001	1μ	10%	35V
C2	"	CK05BX271K	1n0K	10%	00V
C3	"	CK05BX271K	1n0K	10%	00V
C4	"	BS9073 N001	15N	20%	20V
C5	"	CK06BX104K	100n	10%	100V
C6	"	CK06BX104K	100n	10%	100V
C7	"	CK06BX104K	100n	10%	100V
C8	"	CK06BX104K	100n	10%	100V
C9	"	CK06BX104K	100n	10%	100V
C10/C11	"		1n0K		100V
D1	DIODE	IN914			
D2	"	IN914			
D3	"	IN914			
D4	"	IN914			
D5	"	IN914			
D6	" oR	IN914 IN4148			
IC1	DUAL BINARY UP-COUNTER	CD4520BF			
IC2	DUAL 'D' TYPE FLIP FLOP	CD4013BF			
IC3	QUAD NOR R/S LATCH	CD4043BF			
IC4	DUAL BINARY UP-COUNTER	CD4520BF			

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
D	1.10.87							
C	14.3.80							
B	10.10.79							
A	3.4.79							

CERTIFIED | DATE

GRAVINER LTD ENGLAND

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DRAWN J.C.M

TITLE: LOGIC CARD

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SHEET 1 OF 5

CIRCUIT COMPONENT LIST FOR 43761-148-C.D

CIRCUIT REF.	NAME		VALUE	TOL	RATING
IC5	Dual Binary Up-Counter	CD4520BF			
IC6	Quad Bilateral Switch	CD4066BF			
IC7	Quad NOR R/S Latch	CD4043BF			
IC8	Dual Binary Up-Counter	CD4520BF			
IC9	Dual Binary Up-Counter	CD4520BF			
IC10	Quad Bilateral Switch	CD4066BF			
IC11	Quad Voltage Level Shifter	CD40109BF			
IC12	8 Bit Input/Output Port	CDP1852CD			
IC13	N Bit 1 of 8 Decoder	CDP1853CD			
IC14	Strobed Hex Inv Buffer	CD4502BF			
IC15	8 Bit Input/Output Port	CDP1852CD			
IC16	Dual 'D' Type Flip Flop	CD4013BF			
IC17	8 Bit Input/Output Port	CDP1852CD			
IC18	Quad 2 Input NAND	CD4011BF			
IC19	Quad 2 Input NAND	CD4011BF			
IC20	Hex Buffer/Converter	CD4050BF			
IC21	Hex Buffer/Converter	CD4050BF			
IC22	Quad 2 Input NOR	CD4001BF			
IC23	Quad 2 Input NOR	CD4001BF			

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
D	1.10.81							
C	14.3.80							
B	10.10.79							
A	3.4.79							

CERTIFIED

DATE

GRAVINER LTD ENGLAND

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TRACED

DRAWN J.C.M.

TITLE LOGIC CARD

SHEET 2 OF 5

CIRCUIT COMPONENT LIST FOR 43761-148 C D

REF.	[illegible]	[illegible]	[illegible]	[illegible]	RATING
R1	RESISTOR	TR5	470K	5%	---
R2		CR25	1MΩ	5%	
R3		CR25	10M	10%	
R4		TR4	100K	5%	
R5		TR4	100K	5%	
R6		TR4	100K	5%	
R7		TR4	100K	5%	
R8		TR4	100K	5%	
R9		TR4	100K	5%	
R10		TR4	100K	5%	
R11		TR4	100K	5%	
R12		TR4	100K	5%	
R13		TR4	100K	5%	
R14		TR4	100K	5%	
R15		TR4	100K	5%	
R16		TR4	100K	5%	
R17		TR4	100K	5%	
R18		TR4	100K	5%	
R19		TR4	100K	5%	
R20		TR4	100K	5%	
R21		TR4	100K	5%.	

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
D	1.10.87							
C	[illegible].80							
B	10.10.79							
A	3.4.79	-						

CERTIFIED | DATE

GRAVINER LTD ENGLAND

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DRAWN J.C.M

TITLE: LOGIC CARD

SHEET 3 OF 5

CIRCUIT COMPONENT LIST FOR 43761-148-C.D.

REF.	NAME		VALUE	TOL.	RATING
R22	RESISTOR	TR4	100K	5%	
R23		TR4	100K	5%	
R24		TR4	100K	5%	
R25		TR4	100K	5%	
R26		TR4	100K	5%	
R27		TR4	2K7	5%	
R28		TR4	2K7	5%	
R29		TR4	10K	5%	
R30		TR4	10K	5%	
R31		TR4	100K	5%	
R32		TR4	22K	5%	
R33		TR4	22K	5%	
R34		TR4	22K	5%	
R35		TR4	22K	5%	
R36		TR4	22K	5%	
R37		TR4	22K	5%	
R38		TR4	22K	5%	
R39		TR4	22K	5%	
R40		TR4	100K	5%	
R41		TR4	100K	5%	
R42		TR4	7K5	5%	

ISSUE	DATE	ALT SHEET	ISSUE	DATE
D	1.10.81			
C	14.3.80			
B	10.10.79			
A	3.4.79			

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DRAWN J.C.M.

TITLE LOGIC CARD

3 ... 8

REF.	NAME		VALUE	TOL	RATING
R43	RESISTOR	TR4	100K	5%	
R44		TR4	100K	5%	
R45		TR4	100K	5%	
R46		TR4	100K	5%	
R47		TR4	100K	5%	
R48		TR4	100K	5%	
R49		TR4	100K	5%	
R50		TR4	100K	5%	
R51		TR4	22K	5%	

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT SHEET
D	1.10.81							
C	14.3.80							
B	10.10.79							
A	4.9.79	-						

CERTIFIED	DATE
GRAVINER LTD ENGLAND	
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DRAWN J.C.M.	
TITLE. LOGIC CARD	5
CIRCUIT COMPONENT LIST FOR 43761-148-C 2	

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CIRCUIT REF.	NAME	REF. No.	VALUE	TOL. %	RATING
LP1 - LP4	LAMP ASSY				
LP5 - LP8	LAMP ASSY				
LP9 - LP12	LAMP ASSY				
LP13 - LP16	LAMP ASSY				
S.1.	SWITCH ASSY				
S.2.	SWITCH ASSY				
D1	DIODE IN 4007	28544-306			
D2	DIODE IN 4007	28544-306			
D3	DIODE IN 4007	28544-306			
D4	DIODE IN 4007	28544-306			
D5	DIODE IN 4007	28544-306			
C1	CAPACITOR	28475-611	0·1μF	10%	400V
L1	CHOKE	[illegible]-001	500 MH	10%	0-0·40A

ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT. SHEET
D	6.10.81							
C	23.5.80							
B	27.3.80							
A	1.3.79	-						

CERTIFIED | DATE

GRAVINER LTD. ENGLAND

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DRAWN

TITLE: CREW WARNING UNIT

158

SHEET No. 1 OF 1

CIRCUIT COMPONENT LIST FOR: 53813-202

CA 4293/78

CCT. REF.	NAME	REF. No.	VALUE	TOL. %	RATING
R1	RESISTOR	TR4	1K0	5%	
R2	"	"	"	"	
R3	"	"	"	"	
R4	"	"	"	"	
R5	"	"	"	"	
R6	"	"	"	"	
R7	"	"	"	"	
R8	"	"	"	"	
R9	"	"	"	"	
R10	"	"	"	"	
R11	"	"	"	"	
R12	"	"	"	"	
R13	"	"	"	"	
R14	"	"	"	"	
R15	"	"	"	"	
R16	"	"	"	"	
TA	TRANSFORMER	44211-113			
TB	"	44211-113			
TRA	TRANSISTOR	BUX 67C			
TRB	"	BUX 67C			

ISSUE	DATE	ALT SHEET	ISSUE	DATE	ALT. SHEET	ISSUE	DATE	ALT SHEET
A	20/8/80	-						

CERTIFIED

DATE

GRAVINER LTD ENGLAND

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DRAWN J.C.M.

TITLE. 609
ULTRA VIOLET ADVANCED FIRE DETECTION SYSTEM 'A'

SHEET No. 1 OF 1

CIRCUIT COMPONENT LIST FOR.
53813-203 C.D

GAF 4293/78